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Development of 21st century thinking skills in early childhood learners through coding and robotics

by

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Submitted in fulfilment of the requirements for the degree in

Magister Educationist General

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Supervisor: Prof Ronel Callaghan

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DECLARATION

I hereby declare that this document: Development of 21st century skills in early childhood learners through coding and robotics, submitted for evaluation towards the requirements of the M Ed General at the University of Pretoria, is my own original work and has not previously been submitted to this, or any other institution of higher learning or subject for evaluation. All sources used or quoted in this document are indicated and acknowledged by means of a comprehensive list of references.

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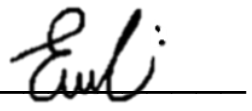
Signature: 

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CLEARANCE CERTIFICATE	CLEARANCE NUMBER: **EDU073/20**
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- Compliance with approved research protocol,
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ETHICS STATEMENT

The author, whose name appears on the title page of this dissertation, 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.

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Embeth Holly van der Wal

DEDICATION

I dedicate my research to my Heavenly Father. I am grateful for the strength He has given me during this research journey. Secondly, I dedicate this to my family. They have been my rock these past two years - thank you for all the coffees and prayers. Finally, I want to dedicate this research to all the young minds that have passed through my classroom doors and who still will. If I could make a small impact on your lives, I hope I instil a love for learning and a confidence to achieve whatever you put your mind to.

ACKNOWLEDGEMENTS

To have achieved this milestone in my life, I would like to express my sincere gratitude to the following people:

- My Heavenly Father, who provided me the strength, knowledge and perseverance to complete this study.
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ABSTRACT

The rise in dependency on technology has had an impact on the field of education. Specifically, young learners are being encouraged to start engaging with technology, and start developing 21st century thinking skills. There has also been a need to implement coding and robotics in schools, recently in South African schools, at a young age as well. This study aimed to develop a set of guidelines for teachers to implement when planning coding and robotic activities in early childhood education. The guidelines that were outlined in this study were discovered, implemented, and evaluated throughout the study. Therefore, the guidelines outlined in this study could pave the way for other teachers to best support the development of 21st century thinking skills in coding and robotics lessons.

It is important to present opportunities to young learners to gain 21st century thinking skills, that can better equip them with the use of digital technologies. Therefore, by investigating the link between coding and robotic activities in early childhood education and the development of 21st century skills, this study provides ideas on how best to support the development in early childhood learners. The developments in the research illustrate the importance of the teachers understanding when designing and planning the coding and robotic activities designed for young learners. This study thus anticipates the need for early childhood learners to be prepared for the world of work, which implies the development of 21st century skills, specifically in coding and robotics.

Key Terms: 21st century thinking skills; coding; collaboration; communication; creativity; critical thinking; early childhood education; robotics; TPACK framework.

LANGUAGE EDITOR

Exclamation Translations

To whom it may concern

The dissertation entitled, "Development of 21st century thinking skills in early childhood learners through coding and robotics" has been edited, proofread, technically formatted, and reference control has been carried out as of 21 September 2021.

As a language practitioner, I have a Basic degree in Languages, an Honours degree in French and a Master's degree in Assessment and Quality Assurance. I have been translating, editing, proofreading, carrying out reference control, and technically formatting documents for the past 11 years. Furthermore, I am a member of the Professional Editors' Guild (PEG).

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CHAPTER 1 INTRODUCTION

1.1 INTRODUCTION

The purpose of education should be to develop knowledge and skills that best equip a generation of individuals with the power to efficiently use digital technologies, thus extending their opportunities to gain 21st century thinking skills (Trilling & Fadel, 2009). It is important to understand the impact that technology has on young learners, and how to best prepare teachers to support learners for their future. This study investigated how teachers can be supported to help young learners to develop 21st century thinking skills that will aid them in the technology-centred world in which we live. Technology in education is becoming a more concrete concept as technology is more prevalent in the world around us. The concept of coding and robotics is also becoming a common concept for early childhood learners. Thus, this study investigates how to prepare learners with the necessary 21st century thinking skills, by discovering guidelines that teachers can follow when planning coding and robotic lessons that will support the development of these skills in early childhood learners. Early childhood learners comprise children between the ages of three to six years old.

1.2 BACKGROUND

Due to the rise in dependency on technology in the 21st century, there is a wide-spread desire to incorporate technology in the classroom (Palaiologou, 2016). In order to adapt to this rapidly changing world, learners need to develop a lifelong-learning approach (Kaplancali & Demirkol 2017). A lifelong-learning approach is defined by the establishment and incorporation of formal and informal learning opportunities throughout a person's life. This is done to promote the continuous development of the knowledge and skills needed (Laal, 2011). Early childhood education in South Africa aims to provide all children with quality experiences and opportunities to achieve their full potential, beginning in their early years (The South African National Curriculum framework for children from birth to four, 2015). Researchers argue that early childhood education plays a crucial role in equipping learners with the soft skills necessary to create the foundation for lifelong learning. These skills include critical thinking, problem solving, and collaboration (Desire to

Learn, 2018). The focus of this study was on how 21st century thinking skills can be developed through coding and robotics in early childhood learners. This study took place in a fairly affluent and technologically advanced private school in Johannesburg, South Africa.

1.3 PROBLEM STATEMENT

Given the fact that technology is developing at a rapid rate, the workforce should be changing simultaneously to incorporate more technology (Mitchell, Skinner, & White, 2010). The World Economic Forum (WEF) emphasises that the labour market is in need of individuals with the relevant skills required in a technology-driven world (World Economic Forum, 2015). The WEF (2015) further expresses the importance of closing the 21st century skill gap. Therefore, it is important to prepare learners to fill this gap by supporting the development of 21st century skills in education.

Not only is labour impacted by technology, but children are being exposed to technology at a significantly young age (Papadakis, Kalogiannakis, & Zaranis, 2016). In South Africa, there is a gap in the literature with regard to the development of 21st century skills in coding and robotics, specifically in the early childhood age group. The research highlights that fewer than 1% of children in Africa complete school with basic coding knowledge and understanding (Thabo Mbeki Foundation, 2019). Due to young learners' brains constantly changing and developing, there is a need to provide constructive experiences for the learners in order for them to develop the necessary skills (National Research Council and Institute of Medicine, 2000). Moreover, there is a new field in early childhood education that involves coding and robotics. Therefore there is a need for research in early childhood to understand how best to equip young learners with 21st century skills specifically using this new field (Desire to Learn, 2018).

A challenge when implementing coding and robotics in early childhood education is that teachers lack knowledge and understanding about technology in general, and coding and robotics specifically (Bers, 2008). There is thus a need to prepare teachers to teach coding and robotics to young learners in order to develop 21st century skills. Another challenge when implementing coding and robotic activities in

a South African school is the affordability of the different resources, specifically the different technology resources, such as the robots. Therefore there is a need for coding and robotic activities that can be completed that are affordable in order for the activities to be relevant to the South African context.

1.4 RATIONALE

The impetus for this study comes from my own curiosity regarding the field of early childhood education and the impact of technology on education. I am an early childhood teacher, and I have a desire to ensure that my learners are receiving the best possible education possible. I believe that it is crucial to equip learners for the world outside of school, which includes society and the workplace. With the rise in the prevalence of technology and the use of technology in education, it is important to understand the impact that technology has on young learners. Recent developments in research have highlighted the importance of coding for young learners as it encourages them to not only consume technology, but to be producers thereof (Bers, 2018). Thus, gaining a deeper understanding of coding and robotics for early childhood learners, and providing guidelines for teachers to implement this topic to develop the required 21st century skills, could equip learners to succeed in the technology-driven world in which we live.

1.5 RESEARCH QUESTIONS

1.5.1 Main research question

How can coding and robotics support the development of 21st century skills in early childhood education?

1.5.2 Sub-questions

- SRQ1: How can 21st century skills be developed through coding and robotics in early childhood education?
- SRQ2: How can coding and robotics principles be developed in early childhood activities?
- SRQ3: How can coding and robotics activities be designed to best support development in early childhood education?

1.6 PURPOSE OF THE RESEARCH

The purpose of this study was to develop guidelines for designing activities in coding and robotics that support the development of 21st century skills. These guidelines could support teachers to plan and present coding and robotic activities that support the development of 21st century skills in early childhood learners, particularly in a South African context.

1.6.1 Objectives of the study

- To understand how 21st century thinking skills can be developed through coding and robotics.
- To determine the best ways to support the development of coding and robotics principles for early childhood learners.
- To gain detailed insight into coding and robotics in early childhood education and activities that are currently underway.

1.7 DELINEATIONS

The emphasis of this study was not purely on topic of 21st century skills. Although the study includes the development of these necessary skills, it also investigates coding and robotics in early childhood education. The study incorporated the use of offline programmable toys and more tangible activities in comparison to block coding, as proposed in the draft curriculum. This study not only focused on all early childhood learners, but specifically those aged five to six years old.

1.8 KEY THEORETICAL CONCEPTS

Below are the key theoretical concepts that are addressed in this study.

1.8.1 Computational thinking

The term ‘computational thinking’ is defined by Wing (2011) as a “thought process involved in formulating problems and their solutions so that the solutions are represented in a form that can effectively be carried out by an information-processing agent” (p.1). Scholars have yet to provide a formal definition for

computational thinking. However, they agree that computational thinking consists of multiple skills, such as algorithmic thinking, traversing through different levels of abstraction, investigating, understanding problems, and presenting data through the representation of models (Barr & Stephenson, 2011; Grover & Pea, 2013).

1.8.2 Coding and robotics

Coding is seen as a new literacy in the 21st century. Coding is believed to be both a cognitive, as well as a social and emotional activity (Bers, 2018). Resnick and Siegel (2015) define coding as a new type of literacy and personal expression that incorporates technical skills that allow for individuals to organise, express, and share ideas a new way. Robotics is defined as a hands-on experience that develops the understanding of technological and mechanical languages and systems. Simultaneously, it allows learners to adapt to constant change, and encourages them to engage with their knowledge of time, space, and contexts (Jung & Won, 2018). Bers (2018) highlights the importance of starting coding and robotics at a young age as it best prepares learners for the booming computing workforce. It also supports learners' development of a systematic way of thinking and a communicative and expressive language. Studies show that the use of robotics in a school environment encourages interactive learning to take place as it allows learners to engage with their learning activities in a hands-on manner (Isnaini & Budiyanto, 2018).

1.8.3 Twenty-first century skills

Twenty-first century skills are defined as soft skills that better prepare learners for the rapidly evolving digital world. These 21st century skills are classified into three fields: learning and innovation skills; information, media and technology skills; and life and career skills (Eguchi, 2014). This particular study took a closer look at the 'learning and innovation skills' that are further defined as the four Cs (4C skills): Critical Thinking and Problem Solving; Communication; Collaboration; and Creativity and Innovation (Eguchi, 2014). The research states that it is vital for individuals to develop the 4C skills as these promote the ability to control technology, and are the foundation of learning programming, which assists learners

to become decision makers and not just consumers of technology (Rushkoff & Purvis, 2010).

1.8.4 Pre-school learning and philosophy

Psychological research highlights the idea that active engagement with learning naturally supports learners to develop better learning outcomes, especially skills such as retention, understanding, and an active use of knowledge (Perkins, 2006). This links to the philosophy that often accompanies early childhood education, which is that constructive learning transpires during play. Research supports the belief that play links to the development of creative thinking (Russ, 1998). Researchers Bers Ponte, Juelich, Viera and Schenker (2002) confirm this as they have found that early childhood education often incorporates constructivist methodologies that allow young learners to engage in their learning, manipulate materials themselves, and engage in active enquiry; this is done by creating playful experiences. Bers (2018) emphasises the importance of coding in early childhood education as it encourages the development of problem solving, metacognitive thinking, counting, spatial orientation, as well as measurement.

1.9 CONCEPTUAL FRAMEWORK

The framework chosen for this study was the Technological Pedagogical Content Knowledge (TPACK) model. The TPACK model, created by Mishra and Koehler (2006), focused on various elements involved in the successful integration of technology into education. This model highlights three main elements, and their inter-relationships, that affect the use of technology in the classroom: content knowledge; pedagogical knowledge; and technology knowledge (Koehler & Mishra, 2008). The TPACK model has evolved over the years and has now entered a second-generation phase in which it is used to focus on both enhancing research and developing learning activities (Thomas & Schmidt, 2010). Therefore, the TPACK model is now also used for designing and developing activities to equip teachers with a more in-depth and interrelated knowledge and understanding of student learning (American Association of Colleges of Teacher Education, Committee on Innovation and Technology, 2008). The TPACK model focuses on the interconnection of content, technology, and pedagogy to create authentic

teaching and learning environments. Figure 1.1 depicts the TPACK framework that was adapted to this study. This study contextualises the various integrating elements of the TPACK model involved in coding and robotics lessons in early childhood education. This was done in order to gain a deeper understanding of the skills that young learners develop.

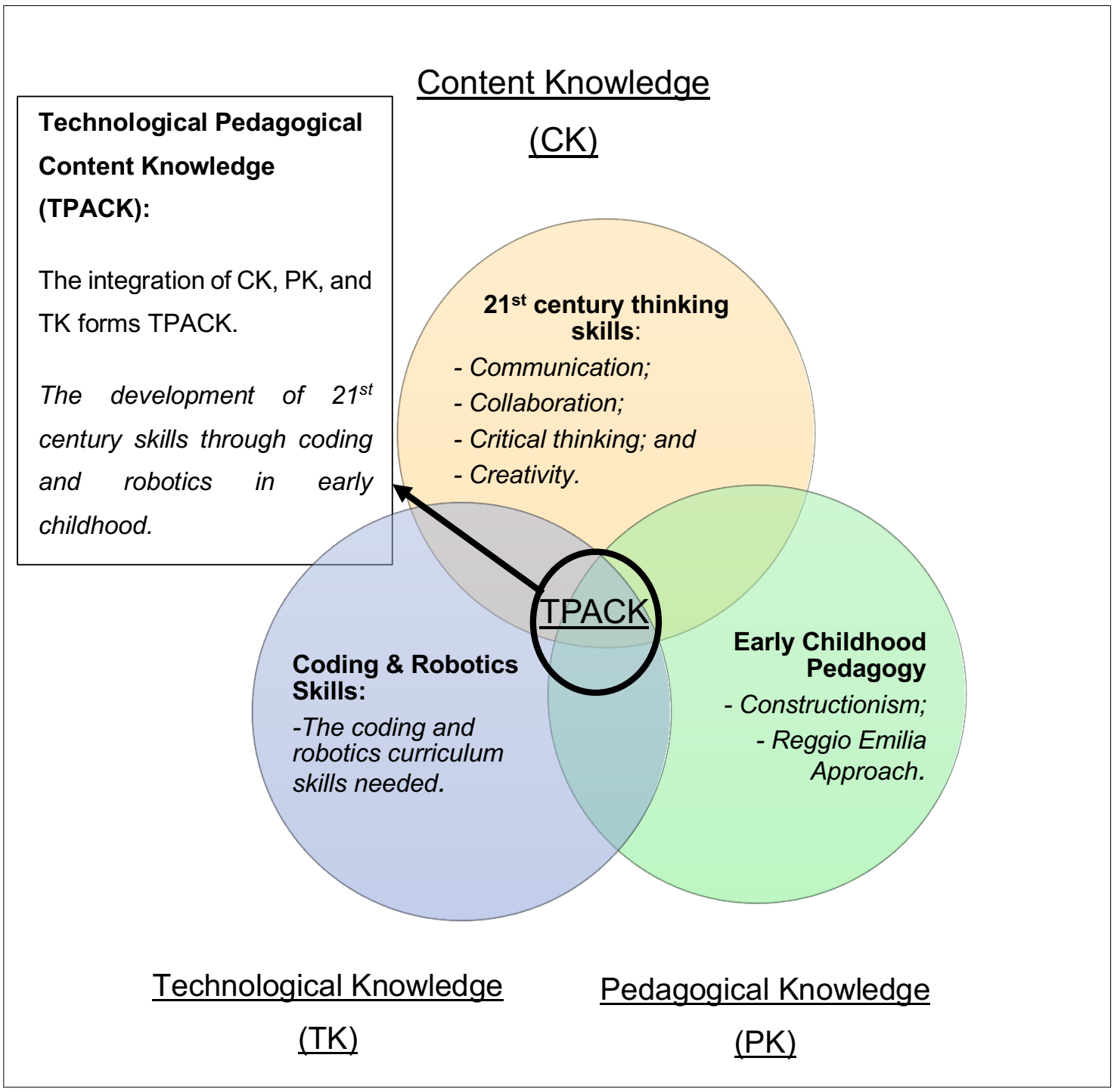


Figure 1-1: Technological Pedagogical Content Knowledge relevant to this particular study

(adapted from Koehler & Mishra, 2008)

1.9.1 Content Knowledge (CK)

Content knowledge is regarded as the subject matter that is addressed and taught in a lesson (Koehler & Mishra, 2008). As illustrated in Figure 1.1, this particular study

focused on the subject matter of 21st century thinking skills. This referred to learners focusing on these specific thinking skills as part of coding and robotics lessons.

1.9.2 Technological Knowledge (TK)

Technological knowledge is defined as a deeper understanding of information technology being addressed; this means that learners are able to apply the same technology to any given task (Koehler & Mishra, 2008). In this study, technological knowledge referred to the understanding of the coding and robotic concepts being utilised in the lessons, as shown in Figure 1.1 above. The learners were required to understand the safety, care, abilities, and constraints of the educational robots, as well as the basic principles of coding.

1.9.3 Pedagogical Knowledge (PK)

Pedagogical knowledge is considered as “deeper knowledge about the processes and practices or methods of teaching and learning, and encompasses overall educational purposes, values and aims” (Koehler & Mishra, 2008, p. 14). The pedagogical approach that was used in this study was constructivism. Constructivism focuses on the learner being enthusiastically involved in a cohesive relationship with the teacher and peers in creating their own understanding. One of the leading theorists of cognitive constructivism is Jean Piaget. Piaget's Theory of Cognitive Development posits that in order for learning to be successful, individuals cannot be given information, but instead should be given the opportunity to construct their own knowledge (Powell & Kalina, 2009). Jonassen (1998) believes that computers as cognitive tools support the construction of knowledge and encourages learners to engage in higher-order thinking. Learning is both social and active, and thus learners will also need to collaborate with one another.

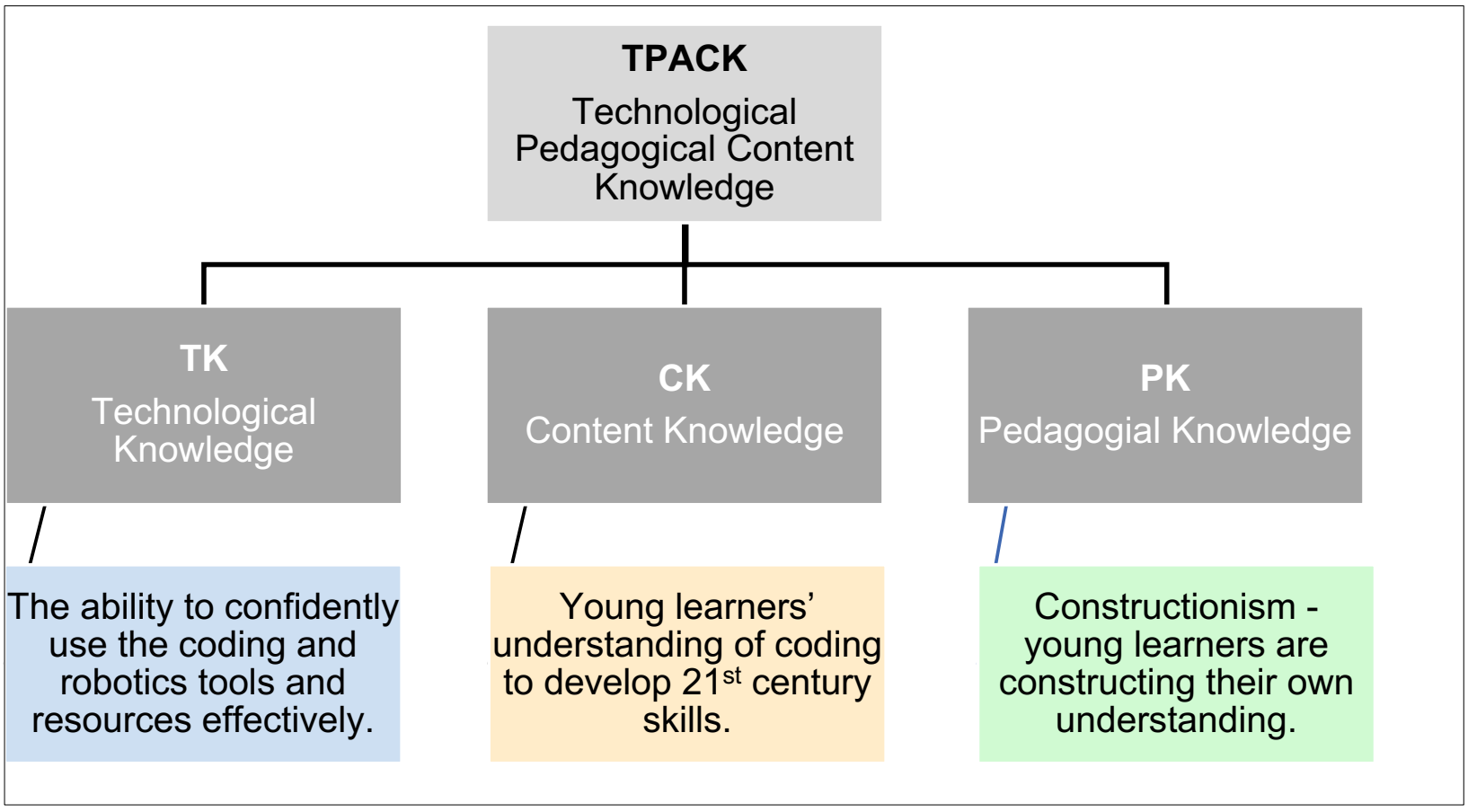


Figure 1-2: The deconstruction of TPACK in this study

As seen in Figure 1.2 above, this study closely investigates the intersection of the CK, PK and TK that emerges in TPACK. This involved the content of coding and robotics being integrated into technology. This study also focused on the pedagogical approach used by teachers, thus investigating the skills that are being developed in early childhood learners. TPACK is not a framework that focuses on isolated elements, but is rather a framework that focuses on how these elements of knowledge interact with each other to provide effective learning. In summary, this study investigated how 21st century skills can be developed in coding and robotics for early childhood learners.

1.10 DISSERTATION STRUCTURE

In order for this dissertation to be well-structured, the content will be presented and outlined as shown in Figure 1.3 below.

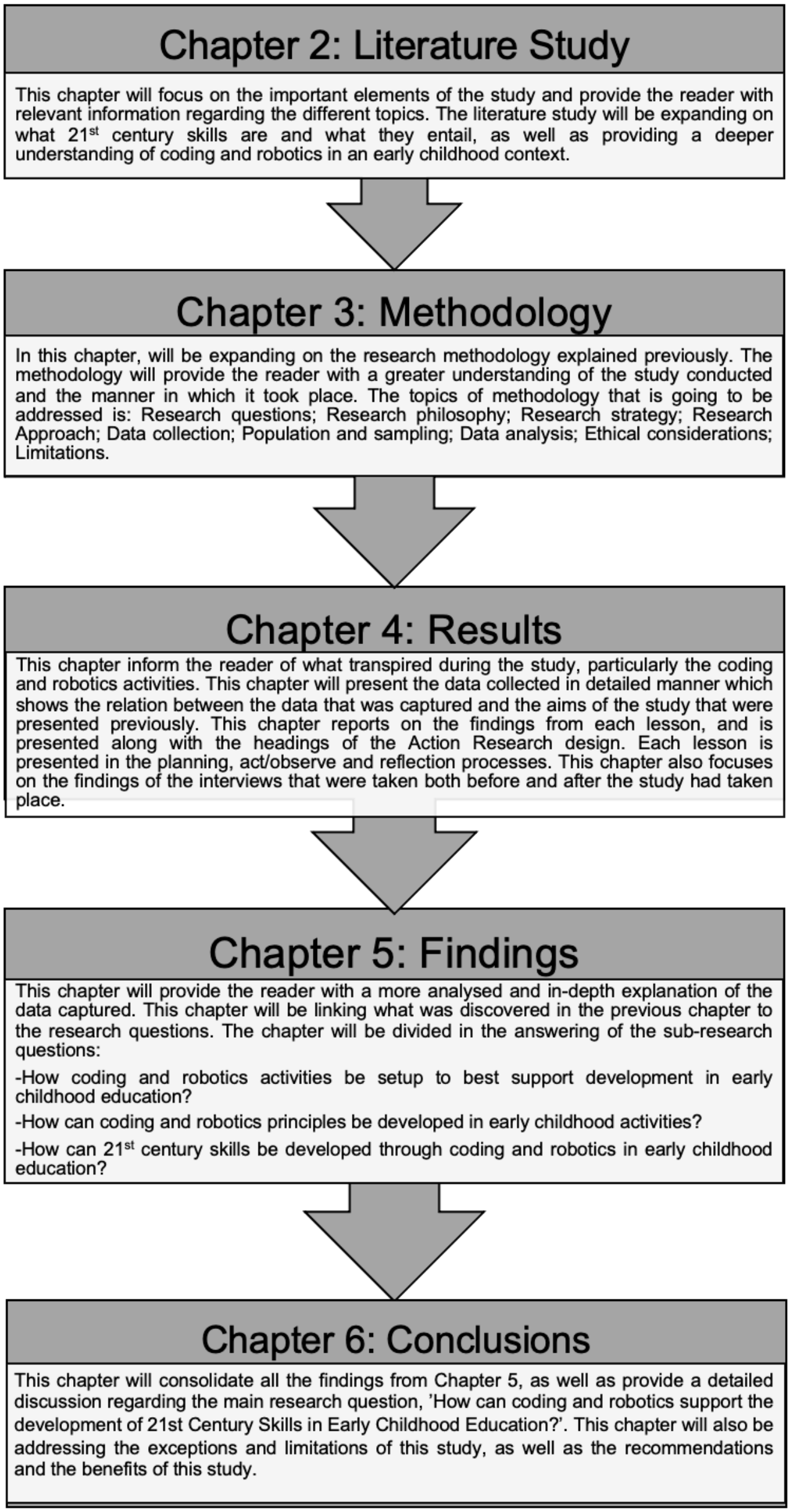


Figure 1-3: Summary of the chapters in this dissertation

1.11 CHAPTER 1 SUMMARY

This chapter aimed to introduce the study and provide the background context of the study. This study highlights the importance of understanding the impact that technology has on young learners, and how to best prepare teachers to support learners for their future. This study focuses on equipping teachers with guidelines that can aid them when planning coding and robotic lessons in early childhood education. This is specifically necessary to support the development of 21st century thinking skills, which will benefit children in the technology-centred world in which we live. The next chapter will investigate the different topics discussed in the study in detail, providing the reader with the relevant literature, as well as a more detailed explanation of the conceptual framework used in this study.

CHAPTER 2 LITERATURE REVIEW

2.1 INTRODUCTION

This chapter will address the topics illustrated in the Figure 2.1 below. Each topic represents a key element that supports the development of specific skills required for young children in a digitized world. Each topic will have a significant part in the conceptual framework that will be discussed later in this chapter.

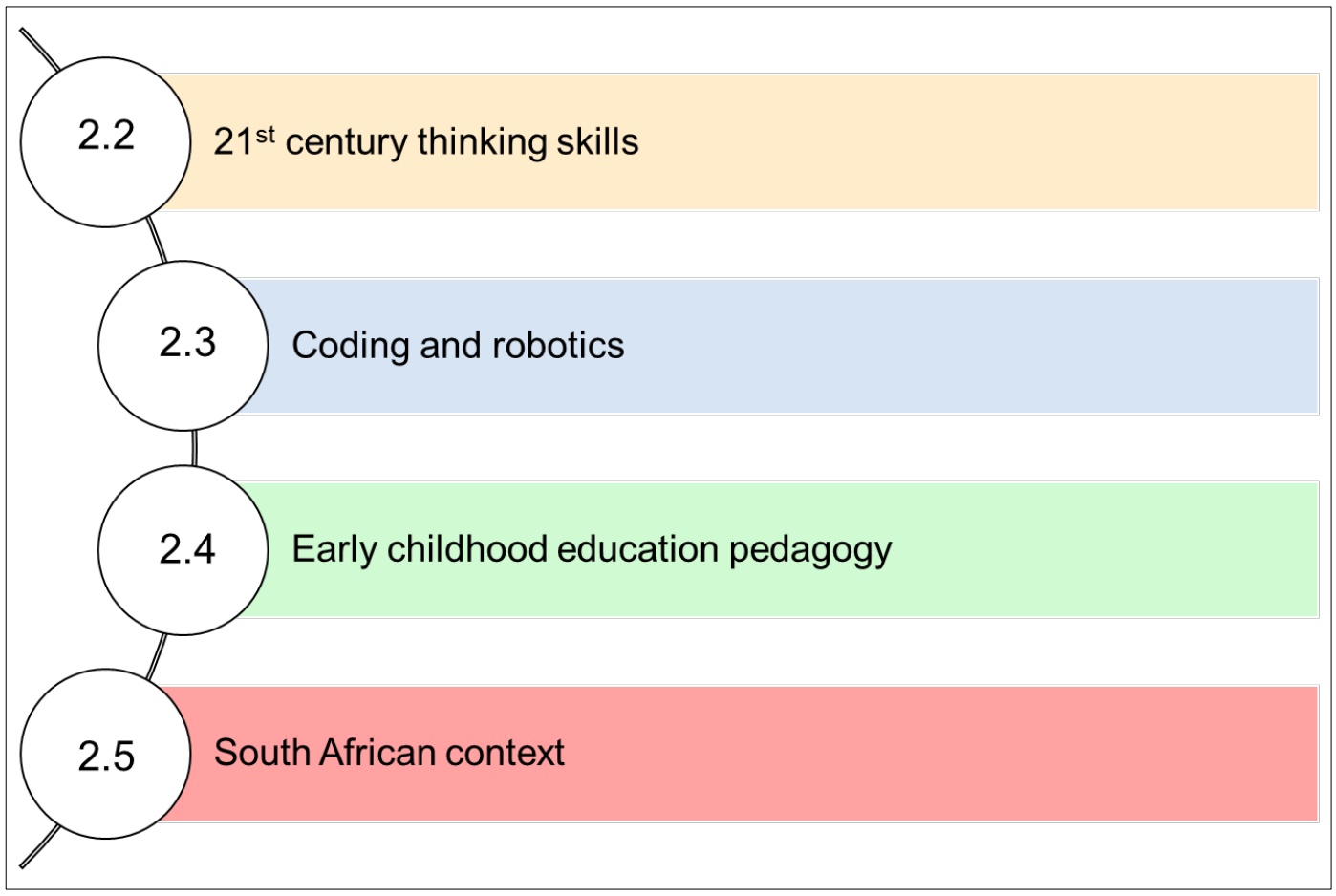


Figure 2-1: The key topics discussed throughout the study

Children are currently being exposed to technology at a much younger age than before. This is due to the fact that children are being raised in a digitised world where technology is swiftly changing and evolving. These children, who can be seen as ‘digital natives’, are required to develop new skills and abilities that are relevant to these technologies (Papadakis, Kalogiannakis, & Zaranis, 2016). The literature suggests that children are learning how to use technological devices before they know how to read and write, meaning that technology is becoming an integral part of the lives of young children (Kaplancali & Demirkol 2017). Many children are now being raised in home environments where there is a wide variety of different technologies, thus it can be said that children’s digital imprinting starts from birth (Palaiologou, 2016). The skills that children are required to develop are advancing

due to the influence of technology in the world around them. Therefore, teachers are encouraged to support children's learning and aid in the development of the required technological skills (Falloon, 2013).

2.2 TWENTY-FIRST CENTURY SKILLS

Researchers define 21st century thinking skills as new competencies that individuals need to possess in order to contribute to the knowledge of society, which includes knowledge, skills, and depositions (Voogt & Roblin, 2012). Due to the rapidly changing world in which we live, teachers and schools are given the responsibility of preparing and empowering learners for the "educational demands of life and work, by equipping learners with the required skills" (Cretu, 2017, p. 1). Therefore, it is vital for schools to start preparing learners for the required competencies that will best support them in the future. The research shows that in order to succeed in the rapidly changing workforce, individuals are required to have certain soft skills. Mitchell, Skinner and White (2010) explain that "employers' rate soft skills the highest in importance for entry-level success in the workplace" (p. 44). These soft skills are defined as 21st century skills.

2.2.1 Categories of 21st century skills

As seen in Figure 2.2 below, 21st century skills are classified into three fields: learning and innovation skills; information, media, and technology skills; and life and career skills (Eguchi, 2014). These fields combine to create a collection of skills and knowledge that will best support individuals in the future. This study will only be invesitgating the one field in-depth.

The first field that will be discussed is information, media and technology skills. As illustrated in Figure 2.2 below, this field addresses learners' information and media literacy, as well as their Information and Communication Technology (ICT) skills. The concept of ICT is defined in the literature as a "form of technology used for creating, displaying, storing, manipulating, and exchanging information" (Chen, Chen, Lin, & Liu, 2018, p. 114). In this digital era, the use of ICT is considered to provide learners with opportunities to apply these new skills parallel to the set curriculum content (Ghavifekr, Kunjappan, Ramasamy, & Anthony, 2016). Literature

that focuses on ICT in early childhood education suggests that the effective use of ICT increases young learners' level of achievement. It also encourages learners to attain higher-order thinking and reasoning skills as they access and evaluate different information (Wajszczyk, 2014). This highlights the relevance of incorporating ICT into the modern classroom as it prepares children for life outside of school.

The second field of 21st century skills explored is life and career skills. This field focuses on an individual's basic life skills. This is defined as a particular set of personal aptitudes necessary for an individual to succeed within the professional and personal sphere (Joynes, Rossignoli, & Fenyiwa Amonoo-Kuofi, 2019). These personal aptitudes include flexibility and adaptability; initiative and self-direction; social and cross-cultural skills; productivity and accountability; and leadership and responsibility (Trilling & Fadel, 2009).

The third field classified in 21st century skills is learning and innovation. This study will only focus on learning and innovation skills and will provide a detailed description below.

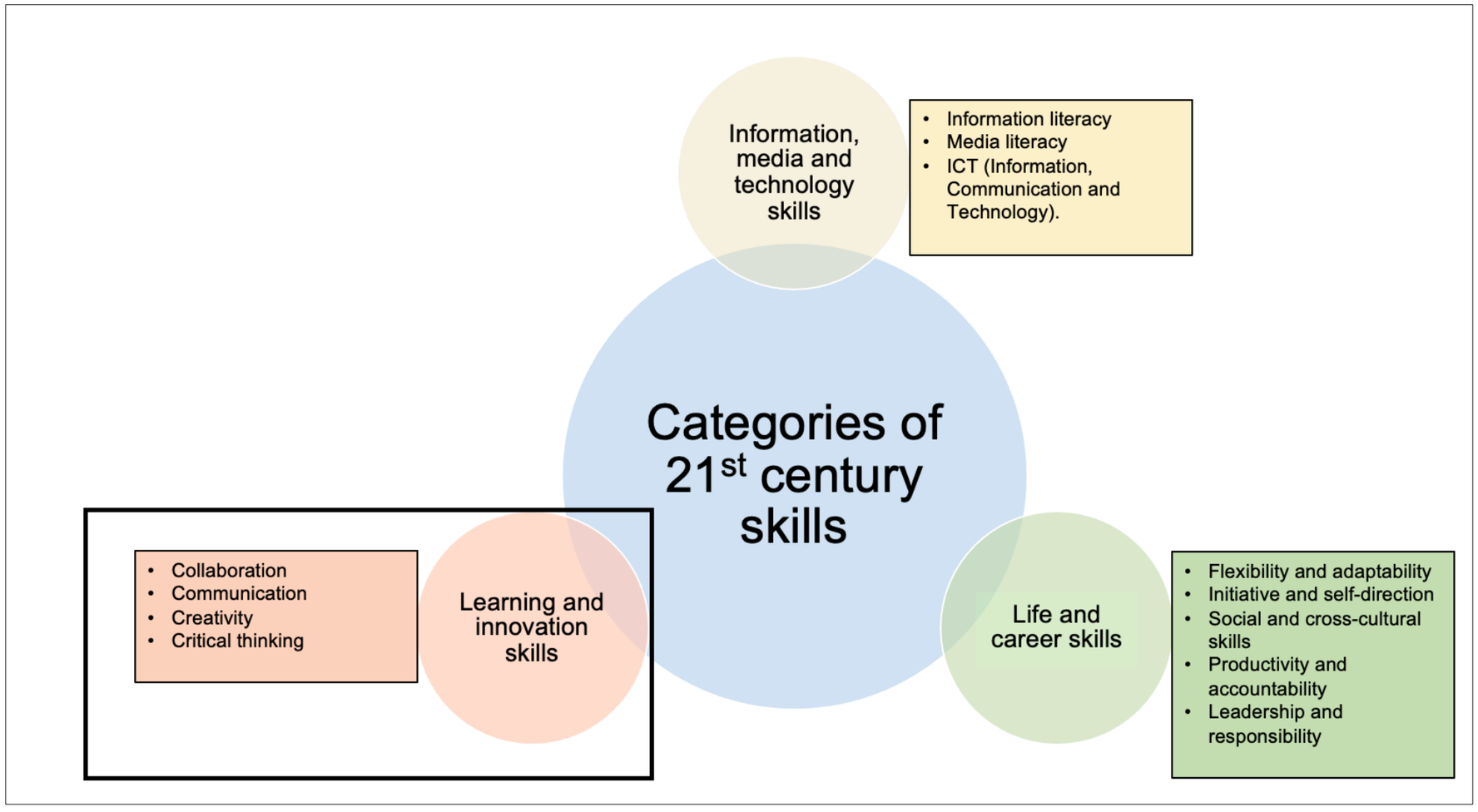


Figure 2-2: The categories of 21st century skills

(adapted from Eguchi, 2014)

2.2.2 Learning and innovation skills

Learning and innovation skills are further defined as the 4Cs: communication; creativity; collaboration and critical thinking (Eguchi, 2014). Rushkoff and Purvis (2010) highlight the importance of developing these skills as they find it to be vital for individuals to be able to control technology. The authors further express the need for individuals to learn how to code in order to make their own decisions instead of only being consumers in the modern digital age in which we live. This highlights the importance of incorporating coding and robotics into curricula. Bers (2018) states the crucial need for young learners, specifically pre-schoolers, to be exposed to programming and working with digital tools. The four learning and innovation skills are discussed in the following paragraphs.

2.2.2.1 Communication

Lippl (2013) defines communication as the basic skill of understanding and sharing ideas. Successful communication has always been a fundamental skill for success in everyday life. However, the literature stresses that sound communication is more crucial now than ever before. It is believed that due to the increase in 21st century information, media and digital technologies, there is a greater need for individuals to develop effective communication skills (Kivunja, 2015). Hobbs and Frost (2015) state that focusing on the development of communication skills in schools is considered to encourage the development of creativity, and allows learners to develop their self-expression. These skills also promote the enhancement of workplace skills such as teamwork (Hobbs & Frost, 2015). These communication skills are evolving as they become more diverse and more important than before. Gerald (2015) proposes that in today's competitive world, an individual's ability to share solutions, ideas and questions is fast becoming the most sought-after attribute in careers. Thus, an individual's ability to communicate is a significant and desired life skill.

2.2.2.2 Creativity

In the Cambridge Dictionary (2013), creativity is defined as "the ability to produce or use original and unusual ideas". Researchers support the idea that creativity no longer links solely to being artistic, but is fundamental to a variety of skills such as

scientific thinking, entrepreneurship, design thinking, and mathematical thinking (Bialik & Fadel, 2015). Creativity and innovation are vital in the global economy as it is driven by digital technologies and information, and there would be no progression made without these (Scott, 2017). Thus, creativity is an important skill for individuals to develop in order to be active participants in the world of work. Creativity is one of the 4C skills that are essential for success in modern living (Kivunja, 2015).

2.2.2.3 Collaboration

Researchers Kift, Israel & Field, (2010) define collaboration skills as teamwork, the ability to work with diverse people in groups, and to work cooperatively with other individuals. With the modern world becoming more connected due to an increase in technology, particularly during the COVID-19 pandemic, it has become more prominent that individuals should have the ability to collaborate. Researchers believe that effective collaboration can lead to an increase in proficiency, not only in education or in increased productivity in the workplace, but also in life after school (Killen, 2013). There are key elements of collaboration that lead to a boost in academic achievement and best prepare individuals for a diverse world. These elements are explained as: the development of listening skills; the ability to ask good questions; and negotiation skills (Alber, 2012).

2.2.2.4 Critical thinking

Critical thinking is a recurring theme in education today. According to the literature, critical thinking is a skill that should be established daily as individuals use this to understand complex problems, and connect information with understanding to construct solutions to solve problems (Handajani, Pratiwi, & Mardiyana, 2018). Trilling and Fadel (2009) believe that the development of critical thinking allows individuals to develop sound reasoning, think systematically, and solve problems effectively. In order for individuals to live successful lives in the modern world, they must possess sound critical thinking skills. The research states that in order for an individual to be effective in the workplace and in their personal lives, it is critical for them to have the ability to solve problems and make sound and constructive decisions (Snyder & Snyder, 2008). Thus, critical thinking is another crucial skill that should be developed in learners today. Researcher Rebecca Stobaugh highlights

the importance of critical thinking in supporting learners in transferring their learning into new scenarios as well as allowing learners to process information at a much deeper level instead of merely memorizing information (Stobaugh, 2019). This is beneficial to a world, that was previously discussed as ever-changing, where young learners are constantly exposed to new scenarios that they are required to process.

2.2.3 21st century skills and impact on this study

With the need to better prepare learners with the necessary skills for the ever-changing world, the investigation of 21st century skills is necessary for this particular study. This study focuses on best supporting the development of these 21st century thinking skills for young learners. Therefore, by having a clear understanding of these skills it allows the study to start focusing on how to best plan and design lessons that equip learners with these skills, as well as the importance and relevance of these 21st century skills for young learners today.

2.3 CODING AND ROBOTICS

2.3.1 Coding, robotics, and computational thinking

The world is constantly becoming more digitised and automated, which has impacted the sustainability of economies, environments, and societies around the world. This change to a more automated world requires people to have a “deeper knowledge and understanding of digital systems” (Curran, Schulz, & Hogan, 2019, p. 8). In the literature, computational thinking tends to be used to refer to a thought process that focuses on the formulation of problems and their solutions. Sequentially, these solutions are represented in a manner that can be effectively conveyed by an information-processing agent (Wing, 2006). Ultimately, computational thinking is a combination of both mathematical and engineering thinking. The research supports the idea that computational thinking is an essential skill for everyone. Thus, it should be added to every young child’s analytical ability along with reading, writing, and arithmetic (Wing, 2006). Technology has a major impact in the world today, meaning that it is important to prepare children for the booming computing workforce, and better to equip children for the fast-changing reality that technology creates.

There has been a rapid increase in modernisation, affecting domains such as economy, technology, automation, social life, and education (Pudiyono, 2019). Technology is becoming the norm for children at much younger ages than before. With the increased focus on and use of technology, there are more jobs that require people who are adroit thinkers (Pudiyono, 2019). Thus, teachers and schools are expected to prepare learners for the educational demands of the modern world of work and life (Cretu, 2017). Therefore it is currently crucial for teachers to start designing high quality and innovative learning activities. Trilling and Fadelstate (2009) agree, stating that the purpose of education should be to create a generation of people that has technological knowledge and skills. This is further supported in the literature as it has been found that involving learners in educational interventions in early childhood is associated with longer-lasting effects (Reynolds, Temple, Ou, Arteaga, & White, 2011; Sullivan, Kazakoff, & Bers, 2013). By combining computational thinking with content disciplines or particular subjects it is believed to likely to assist young learners in applying computational thinking to real-world scenarios (Ching, Hsu & Baldwin, 2018). Therefore, it is important to provide learners with activities that they can relate to and has a particular context to them. Coding is an element of computational thinking that ultimately leads to the enhancement of digital literacy skills. Coding is seen as a new form of literacy in the 21st century and is described by Bers (2018) as a cognitive activity. This type of activity is seen as an expressive medium that allows learners to engage with and develop emotional and social skills while solving problems and acquiring different programming concepts and skills. Bers (2018) further explains that coding “enables new ways of thinking and new ways of communicating and expressing ideas. Furthermore, literacy ensures participation in decision-making processes and civic institutions” (p. 8). Jung and Won (2018) define robotics as “practical experiences for understanding technological and mechanical language and systems; accepting and adapting to constant changes driven by complex environments; and utilizing knowledge in real situations or across time, space, and contexts” (p. 1).

2.3.2 Robots

Educational robotics refers to the teaching practice of using robots to aid in the construction of learners’ knowledge (Misirli & Komis, 2014). This teaching practice involves the use of programmable toys in order to improve the learning process for

learners. Programmable toys are defined in the literature as pre-constructed robotic devices that encourage the learner to design a program and execute it in order to solve a problem or achieve a goal (Hirst, Johnson, Petre, Price, & Richards, 2003). There are multiple programmable toys on the market, for example, the Bee-Bot is a commercial robot that is regarded as a floor robot. In single instruction, the Bee-Bot is able to retain up to 40 instructions in its memory. The Bee-Bot can advance and go backward by 15 centimetres, as well as turn left or right by 90 degrees (Di Lieto Pecini, Castro, Inguaggiato, Cecchi, & Dario, 2020). There is also the Botley robot, designed by Learning Resources®, which is screen free. Which indicates that a screen, such as a computer or iPad is not required in the operation of the robot. The Botley robot has basic coding instructions, similar to the Bee-Bot, but also has more advanced coding concepts such as 'If/Then' statements and loop logic, as well as the ability for it to be programmed for object detection, amongst other instructions (Heljakka, Ihamaki, Tuomi, & Saarikoski, 2019). Another robot designed by the same company is the Coding Critter, which is a programmable toy that follows simple coding instructions, such as forward, backwards, right turn and left turn. The Coding Critter is suitable for children aged four to 10. The Coding Critter was awarded the Pre-school Toy of the Year award in 2020 (Michalik, 2020). This study used the Coding Critter in the presented lessons. In particular the cat, dinosaur, and dog Coding Critter robots were used in this study.

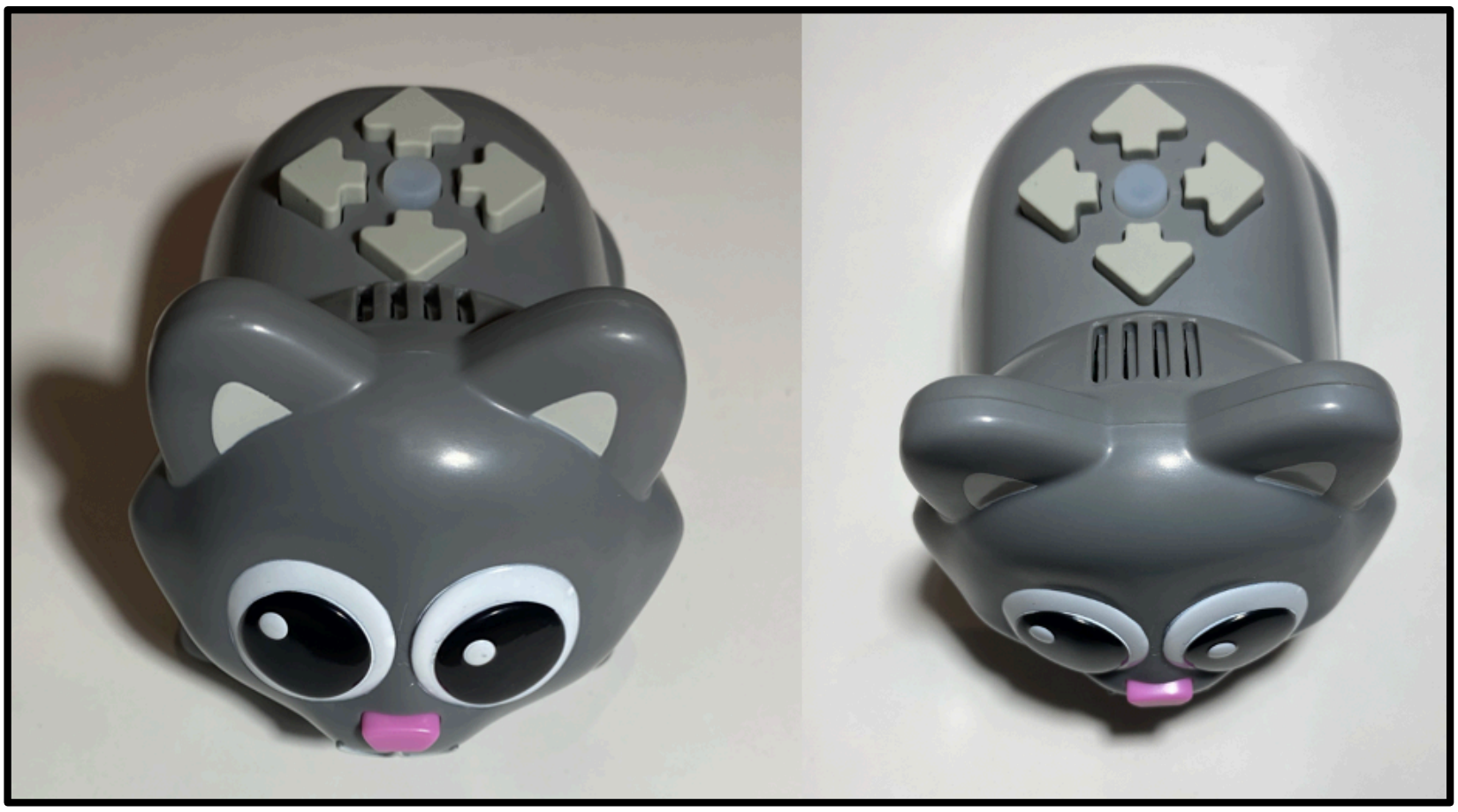


Figure 2-3: Image of the cat Coding Critter that was used in this study

2.3.3 Coding and robotics in pre-school

The goal of implementing coding amongst pre-school learners is to help learners to "solve problems with program design rather than merely memorizing the syntax of the programming language and the operations of the programming tools" (Wang, Huang, & Hwang, 2015, p. 2). The implementation of coding and robotics in pre-school focuses on the thinking skills that are being developed. Research supports the importance of coding for young learners as it encourages children to not only consume technology, but to be producers thereof (Bers, 2018). Moreover, the use of robotics in early childhood education supports the development of problem solving, metacognition, spatial orientation, as well as mathematical skills such as counting and measurement (Rogers & Portsmore, 2004).

2.3.4 The benefits of coding and robotics in pre-school

The teaching of coding in pre-schools is beneficial as learning occurs differently in younger learners as a child's brain is constantly and rapidly changing at this stage due to the influx of experiences that learners face (National Research Council and Institute of Medicine, 2000). Research shows that with the incorporation of coding at a young age there is an improvement in the learner's self-confidence, specifically related to their problem-solving ability (Gülbahar & Kalelioglu, 2014). Learning codes and developing computational thinking are essential skills for children, and will help prepare them for situations they will face later in life, as well as preparing them for collaboration between humans and machines (Garcia-Penalvo, Reimann, Tuul, Rees, & Jormanainen, 2016). The incorporation of coding at a young age is crucial in order to prepare learners for the "booming computer workforce, but more importantly, coding provides a systematic way of thinking and a language for expression and communication" (Bers, 2018, p. 10). The literature suggests that learners who are exposed to computer programming at an early age will face fewer obstacles when entering the workforce (Bers, 2018). By incorporating coding and robotics into pre-school learning, young learners (regardless of gender) are taught the basic skills required for programming. Research has found that teaching coding at a young age will provide learners with a "skill for life" (Kaplancali & Demirkol 2017, p. 32). The skills developed in learning in order to code are required to "fill the 'skills gap' between the number of technology jobs and the people qualified to fill them"

(Kaplancali & Demirkol 2017, p. 32). There are multiple benefits to the incorporation of robotics in early childhood education. Jung and Won (2018) consider the use of robotics in early childhood education to empower learners and provide them with authentic learning. Researchers McDonald and Howell (2011) confirm that the learning of robotics in early childhood education helps learners to show development in literacy and numeracy skills as they expand their terminology and mathematical skills, such as counting. Furthermore, learners show improvement in their level of computational thinking (Bers, Flannery, Kazakoff, & Sullivan, 2014).

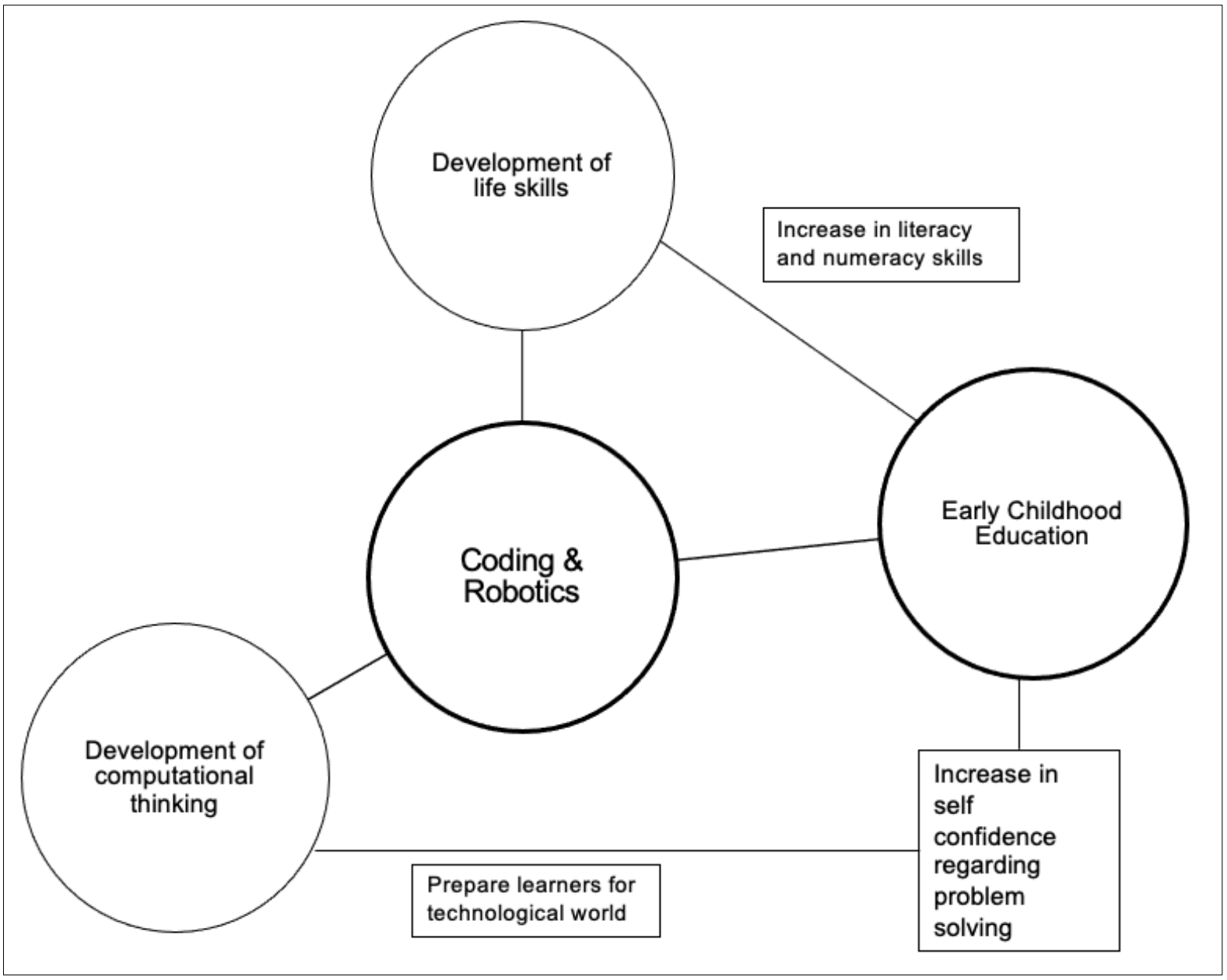


Figure 2-4: The benefits of coding and robotics in association with early childhood education

Figure 2.4 illustrates how the benefits of coding and robotics simultaneously relate to one another. Specifically, coding and robotics in any individual, regardless of age, lead to the development of life skills and the development of computational thinking. With that being said, this relates to early childhood education as those are the key factors involved in the creation of the developmental skills that are implemented in the curriculum at a young age. This ultimately leads to benefits in young learners

such as an increase in literacy and numeracy skills, preparing learners for the technological world. This has also been found to increase their self-confidence with regard to problem solving. The Figure 2.4 shows the link between coding and robotic activities and the discovered benefits, such as the development of life skills and the development of computational thinking, that was discussed in detail previously in this chapter. These benefits are then further linked to early childhood education and the benefits such as; the increase in literacy and numeracy skills, the preparation of learners for the technological world and the increase in self-confidence regarding problem solving.

2.3.5 The challenges of coding and robotics in early childhood education

Despite the obvious benefit of coding and robotics in pre-school, some challenges have been discovered regarding the implementation thereof. One particular challenge when implementing coding and robotics in early childhood education is that teachers often lack knowledge of and understanding about technology and coding and robotics (Bers, 2008). There is thus a need to support teachers in gaining an understanding of coding and robots and how to teach it to young learners. Turkle (2017) expresses her concern regarding the decrease of face-to-face interactions between young learners and other people, which is a result of young learners' interaction with technological devices. However, this notion was addressed as further studies have discovered the benefits for early childhood learners when engaging in play opportunities with technological devices (Granic, Lobel, & Engels, 2014). There is also the challenge of excessive screen time that young learners experience. Research focusing on the medical aspect of the effect that electronic devices has on young children's well-being highlights the danger of excessive screen time for young children (Hinkley, Verbestel, Ahrens, Lissner, Molnár, & Moreno, 2014). However, there are various ways to teach coding and robotics without a technological device, especially in early childhood education. It is therefore important to have a more tangible and play-based approach when teaching young learners coding and robotics (González-González, Guzmán-Franco, & Infante-Moro, 2019). Research supports the idea that the supervised use of technological devices aids the potential development of cognitive, social, and emotional development in early childhood learners (Granic et al., 2014). The use of unplugged activities, activities that do not require a computer or a technological device

component, is necessary for young learners. Researchers Lee and Junoh, believe that it is vital to start with implementing concrete representations of coding to young learners as it allows them to physically move objects without requiring established abstract thinking skills(Lee & Junoh, 2019)

2.3.6 Coding and robotics and the impact on this study

This study is investigating coding and robotics for early childhood learners. With the study focusing on preparing young learners for the digitised world, the study addresses the implementation of coding and robotic lessons as research motivates that coding enables computational thinking (Bers 2018). This study is providing learners with different coding and robotic lessons and observing the learners engagement, the skills being addressed and the overall learning experience. The coding and robotic lessons will be focusing on the development of pre-coding skills and basic robot care and understanding.

2.4 EARLY CHILDHOOD EDUCATION PEDAGOGY

2.4.1 Pre-school philosophy

Early childhood education is vital to the foundation skills that individuals are expected to acquire. It is believed that for better retention and understanding, children should be actively engaged in their own learning (Perkins, 2006). This links to the learning theory of constructivism. Piaget, a leading theorist of cognitive constructivism, believed that in order for learning to be successful, learners should be presented with opportunities to construct their own knowledge (Powell & Kalina, 2009). The constructivist view of learning posits that the young learner is an active role-player in the acquisition of their own knowledge (Olusegun, 2015). Researchers believe that constructivism supports the engagement of learners in their learning, and promotes their ability to manipulate the tools involved in their learning, this is achieved by active enquiry and the construction of playful experiences (Bers et al., 2002). This is supported by a constructivist researcher who believes that individuals construct their own knowledge and their own meaning from experiences (Olusegun, 2015). It is believed that incorporating robotics and computer programming in early childhood education can aid in the development of various cognitive and social milestones and skills (Sullivan & Bers, 2015). The primary goal in teaching young learners coding and robotics is not to teach them coding itself, but to develop skills

and increase learners' motivation through using different tools that encourage the development of 21st century skills (Koç & Boyuk, 2013). Research supports the notion that teaching robotics to young learners helps develop the learners' fine motor skills and hand-eye coordination, simultaneously engaging the learner in collaboration and teamwork scenarios (Kanbul & Uzunboylu, 2017). Robotics in early childhood is a tool that allows young learners to make abstract ideas far more concrete as they can directly observe the robot's actions in correspondence to their programming commands (Sullivan & Bers, 2015).

2.4.2 Reggio Emilia philosophy

The Reggio Emilia philosophy is a world-renowned curriculum that focuses on an authentic, learner-centered learning experience. The Reggio Emilia approach was developed after the Second World War by families and an early childhood educator and philosopher, Malaguzzi, in Reggio Emilia city in Italy. The Reggio Emilia approach focuses on developing a learning environment that focuses on stimulating young children's social, cognitive, lingual, and symbolic skills (Rinaldi, 2003). This stimulating learning environment encourages the learners to fully participate in their own learning and gives them the opportunity to explore. Researchers believe that the Reggio Emilia approach focuses on presenting children with concrete experiences which allows them to make new discoveries on their own (Edwards & Springate, 1995). The Reggio Emilia approach links to the constructivist teaching methodology as in both philosophies children are active participants in their own learning. Piaget found that a child's active, physical interaction with the environment around them aids in their construction of knowledge (Malaguzzi, 1993b).

2.5 THE SOUTH AFRICAN CONTEXT

The World Economic Forum (2020) highlights the importance of integrating technology skills into early childhood education as they have discovered that in order for children to productively contribute to the future economy, they are required to develop these necessary skills. Although coding and robotics are becoming a popular topic in research, there is still a need for more comprehensive and detailed investigations that focus on early childhood learners and their engagement with educational robots, as well as what they learn through robotics and coding (Toh,

Causo, Tzuo, Chen, & Yeo, 2016). In South Africa, coding and robotics is featured in many schools, however there is very little research in regard to early childhood education. President Cyril Ramaphosa announced in the State of Nation Address 2020 that the government would be introducing coding from Grade R to Grade 3 in two thousand schools nation-wide. This emphasises the importance of research in this field. Further to this, the South African Department of Education (DoBE) has released a new draft curriculum for coding and robotics that starts at Grade R and continues to Grade 9 (Department of Basic Education (DoBE), 2021, p. 13). This draft curriculum was made public while this study was being conducted. The draft curriculum aims to support learners in the areas of Information Technology and Engineering. The draft curriculum focuses on specific content areas such as: "pattern recognition and problem solving; algorithms and coding; robotic skills; internet and e-communication skills; application skills" (Department of Basic Education (DoBE), 2021, p. 13). A challenge that is presented to South African schools, as in many developing countries schools, is the affordability and accessibility to resources required to teach coding and robotics. Moreover, research has found that South African schools face many challenges when integrating technology into the classroom, such as the lack appropriate resources, time, teacher education and space (Torres & Giddie, 2020).

This study focuses on a constructivist learning philosophy as the lessons designed in the study focus on the concrete experiences that the learners engage in to build their own understanding and development of skills. The lessons in this study incorporate a variety of different activities, some using a robot, some using affordable toys, some using the learners body and movement, while others simply using paper. The use of the various activities in the study not only provides a hands-on learning experience to the young learners, but also provides teachers with multiple ideas on the incorporation of different resources, whether the teachers are at an affluent school and can afford more costly resources or at a school with limited resources.

2.6 THEORETICAL AND CONCEPTUAL FRAMEWORK

2.6.1 Theoretical framework

As explained earlier in Chapter 1, the framework chosen for this study is the Technological Pedagogical Content Knowledge (TPACK) framework. The TPACK

framework was originally proposed in 1987 by Shulman the Pedagogy Content Framework (PCK), which was later expanded with a technological component by Mishra and Koehler (2006). Shulman's (1987) framework highlights the relationships between the subject-matter knowledge, which is regarded as the content, and the various ways to teach it, which refers to pedagogy. Mishra and Koehler (2006) believe that it is important for teachers to display knowledge in three different domains when planning lessons that integrate technology. Teachers need suitable knowledge of the content of the lesson, as well as the pedagogical knowledge of the lesson. This relates to Shulman's (1987) PCK, and the technological knowledge needed for the lesson. This framework highlights the importance of an effective integration between the different knowledge domains that lead to a successful lesson, particularly relating to the integration of technology (Niess, 2008). TPACK is a flexible framework proposed to assist teachers when designing and implementing a curriculum while incorporating digital technologies to guide learners' thinking and learning (Niess, 2012).

Mishra and Koehler (2006) explain the three domains in detail: Content Knowledge (CK) is referred to as the subject-matter knowledge that is intended to be taught in the lesson. Pedagogical Knowledge (PK) refers to teachers' own knowledge regarding the methods and strategies of instruction that lead to children's learning. Lastly, Technological Knowledge (TK) refers to teachers' own understanding of technology and how its integration into the curriculum impacts children's learning (Koehler, Mishra, Kereluik, Seob Shin, and Graham, 2014). As seen in Figure 2.5 below, each domain in the TPACK framework integrates with one another to create a series of relationships. Thus, the TPACK model aids in the designing and developing of learning activities as teachers gain a more in-depth and interrelated understanding of students' learning (Niess, 2008).

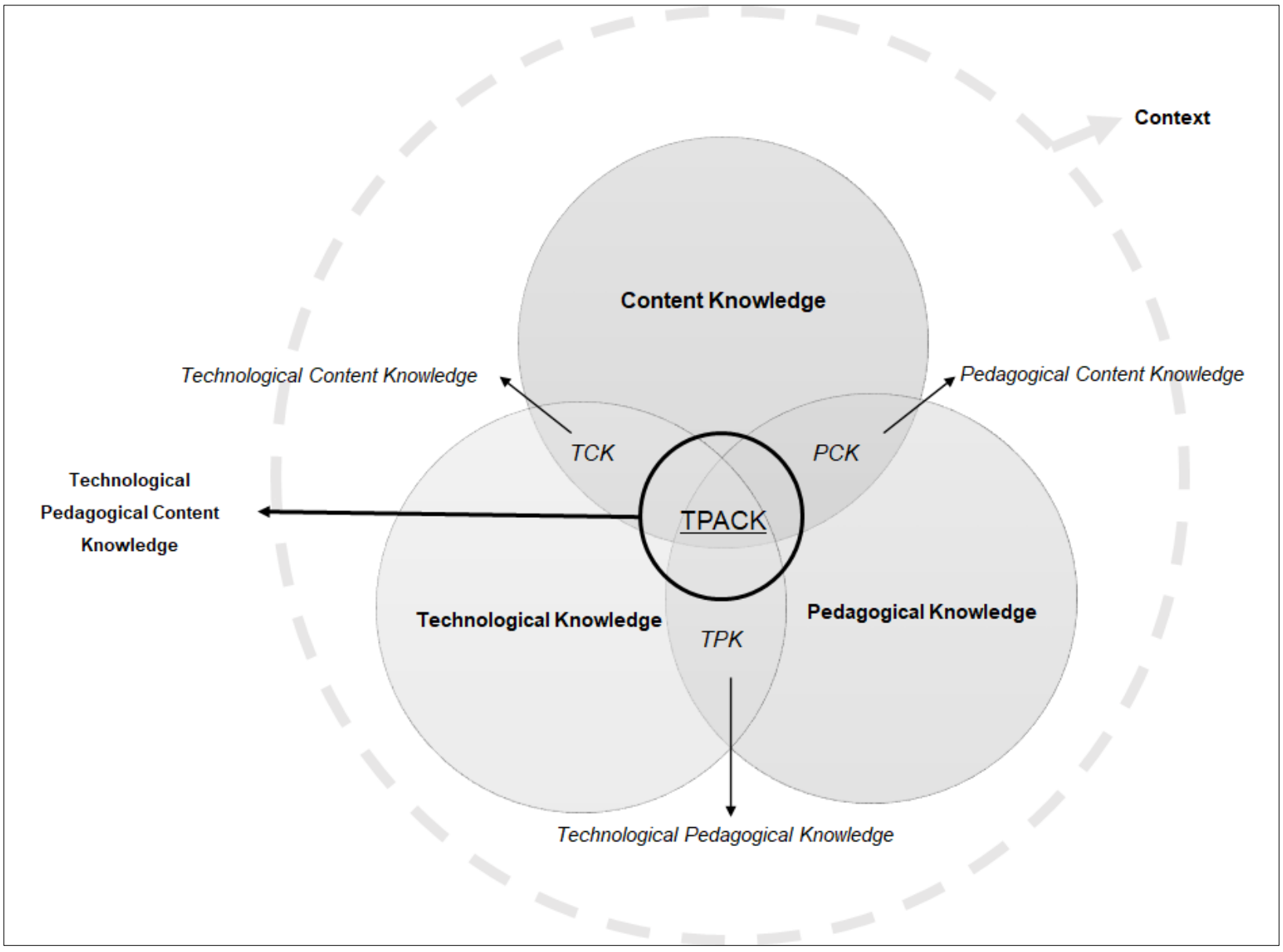


Figure 2-5: TPACK Framework showing the relationship between the different domains

(adapted from Koehler & Mishra, 2008)

The three main domains link with one another to represent the three secondary knowledge domains: PCK; TPK; and TCK. The CK and PK domains link to form the Pedagogical Content Knowledge (PCK) domain, as found in Shulman's proposed framework (Niess, 2012). PCK focuses on understanding how instructed knowledge is organised and presented to learners, specifically in terms of learners' abilities and interests (Shulman, 1987). As seen in Figure 2.5 above, the PK and TK domains intersect to form the secondary domain of Technological Pedagogical Knowledge (TPK). The TPK domain focuses on the existence of teachers' technological knowledge to support their teaching strategies (Koehler & Mishra, 2008). Lastly, the secondary domain of Technological Content Knowledge (TCK) is constructed on the intersection of the TK and CK domains. The TCK domain is defined by Koehler and Mishra (2008) as "knowledge about the manner in which technology and content

are reciprocally related" (p. 1028). All of these domains intersect in the middle of the figure to form the Technology, Pedagogy and Content knowledge (TPACK) model. The TPACK model helps teachers to consider how their knowledge domains intersect in order to effectively teach and engage learners with technology. Pierson (2001) supports the notion that the intersection of all of these domains leads to true technology integration in learning. In Figure 2.5 above, the dashed-line circle encompassing the figure represents the context in which the TPACK is embedded. This context is constructed of unique factors such as students' individual background, parental concerns, and the school network (Mishra & Koehler, 2008). Mishra and Koehler (2006) explain the importance of understanding the interweaving of the different domains as quality teaching requires the teacher to have a complex understanding of the relationships between technology, content, and pedagogy. Teachers must use this knowledge to design lessons accordingly.

2.6.2 Conceptual framework

As discussed above, the original purpose of the TPACK is to focus on the different knowledge domains. Understanding the intersection of these domains' aids in teachers' ability to teach and engage learners effective in technology-based lessons. This framework was implemented in this study as it aimed to develop successful coding and robotics lessons that led to the development of 21st century skills in early childhood learners. In this study, the TPACK framework was adapted to focus on the TK, PK and CK domains, as well as the central intersection thereof (TPCK). Although the secondary domains do have a purpose, these will not be addressed in this study. The key elements being investigated in this study are depicted in Figure 2.6 below where these elements are placed in the appropriate domain to form the TPACK framework the respective domains. The CK domain refers to the 21st century skills that the study set out to observe regarding the development thereof in early childhood learners. The PK domain refers to the early childhood learning pedagogy, which focuses on a learner-centred approach and allows the learners to construct their own understanding through the activities presented to them. The TK domain refers to the coding and robotic skills that the young learners are intended to develop through the different activities.

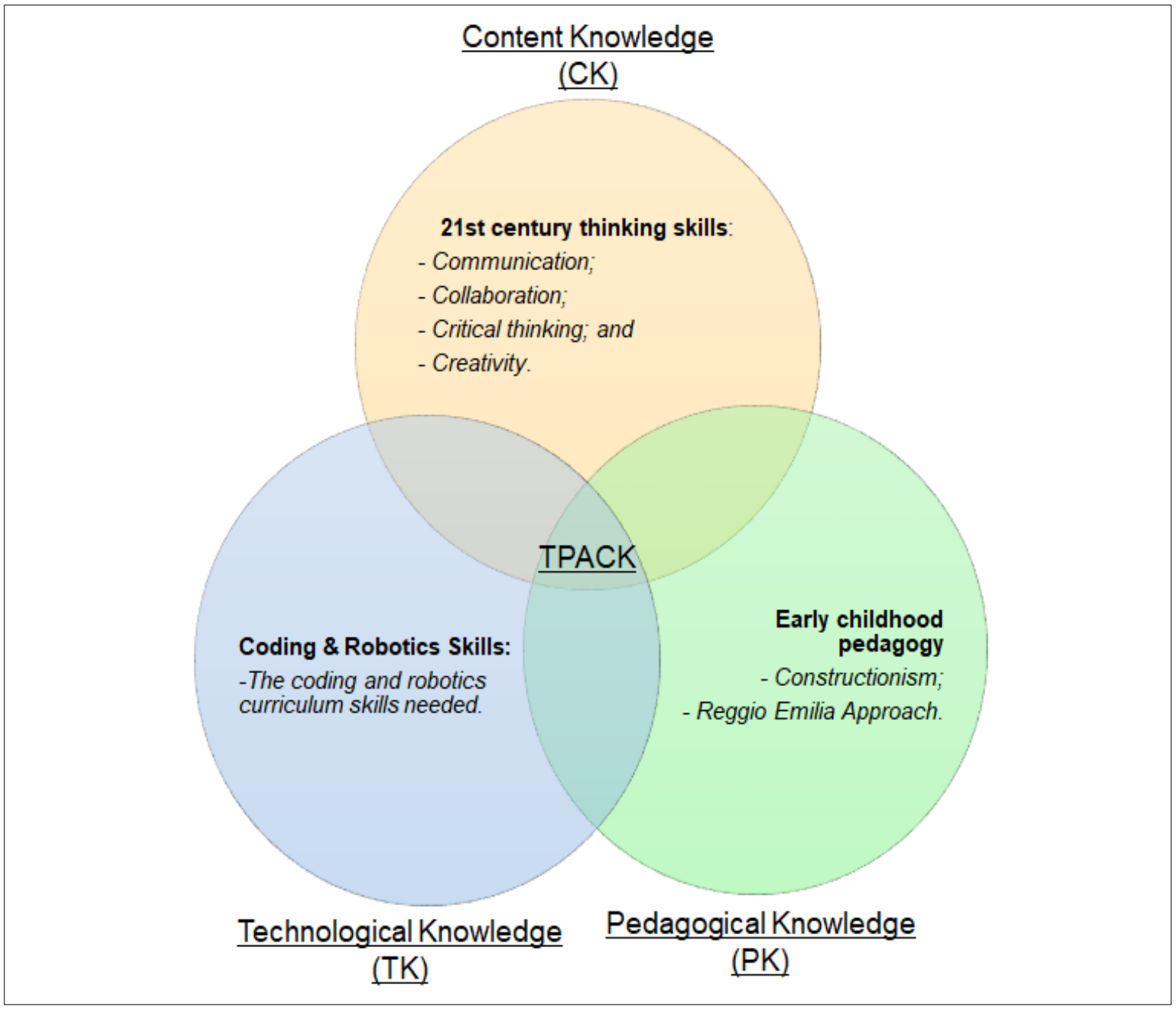


Figure 2-6: The integration of key elements to support the development of skills required for young children in a digitised world

(Adapted from Koehler & Mishra, 2008)

Each of the domains displayed in Figure 2.6 above play a role in the construction of an effective lesson (Pierson, 2001). This framework was implemented in the planning of the lessons presented to the early childhood learners in this study. This framework relates to the different research questions that this study aimed to address. Furthermore, this study aimed to explore each element presented in the TPACK, therefore each element was investigated through a sub-research question, as seen in the figure below. Figure 2.7 below represents each domain and how it relates to a particular sub-research question. Thus, the integration of all of the domains led to the development of the main research question: how can coding and robotics support the development of 21st century skills in early childhood education? Exploring the sub-research questions allowed the researcher to gain an answer to the main research question above and provided a clearer understanding of the topic.

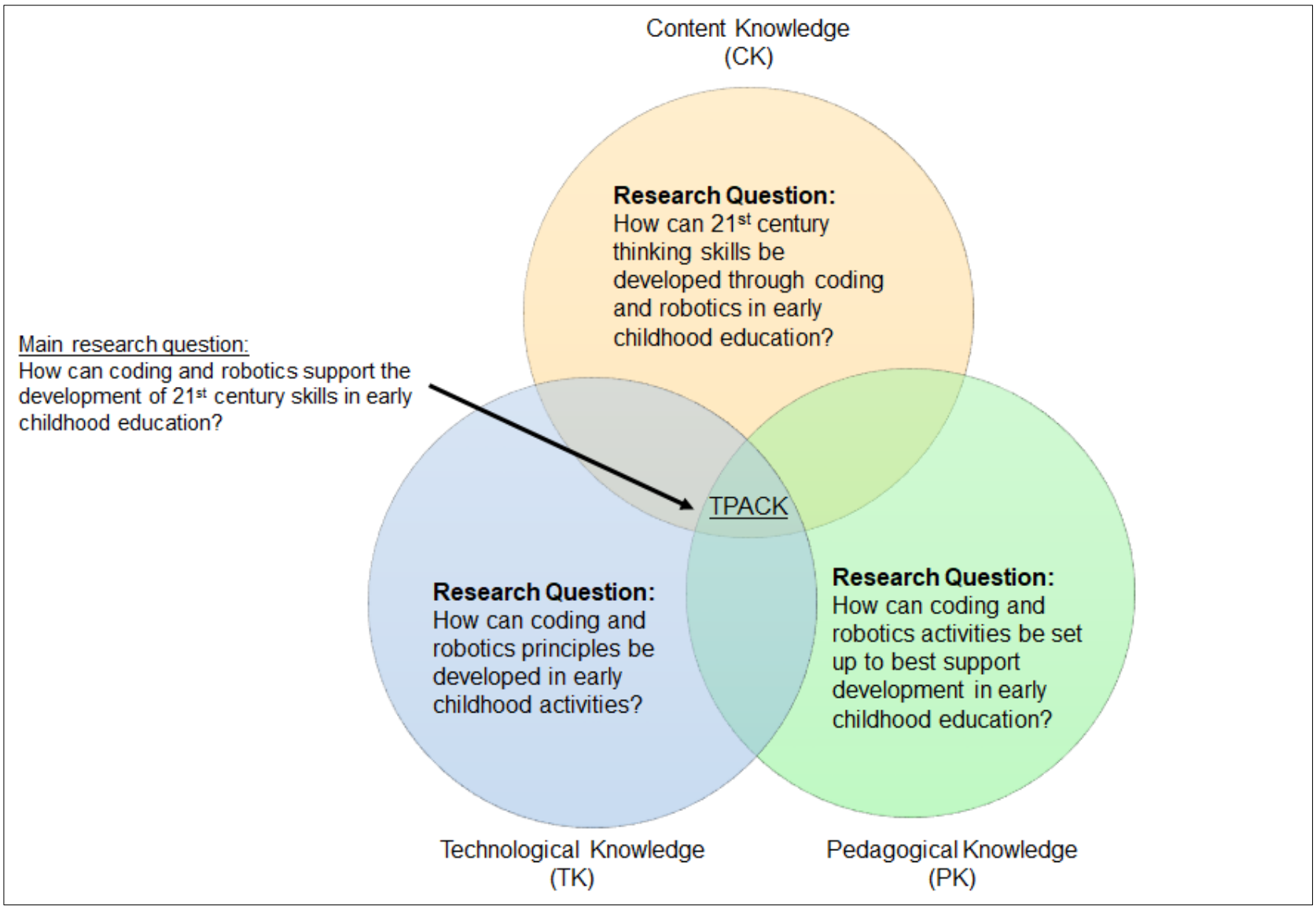


Figure 2-7: The relationship between the research questions and the TPACK framework

2.6.3 TPACK framework and the impact on this study

The conceptual framework that was discussed in detail above will be implemented in both the design of the different lessons as well as the foundation of the study and the different research questions being investigated. The study will be incorporating the underlining generic theory of the study. However, the study will not be addressing the overlapping sub-intersections between each of the domains, but the three main domains and the main intersection between all three, known as the TPACK.

2.7 CHAPTER 2 SUMMARY

In conclusion, emphasis has been placed on coding and robotics and the importance thereof in preparing learners for the digital world. Young learners are required to develop certain skills that can better assist them in the world of

technology. Therefore, it is crucial for young learners to develop these skills at an age where the brain is constantly and rapidly developing. As explained above, it is important for teachers to have an understanding of the required 21st century skills to better equip learners for the future. The following chapter will provide the reader with a more detailed explanation of the design and methodology of this study.

CHAPTER 3 METHODOLOGY

3.1 INTRODUCTION

This chapter unpacks the research methodology and design of this study as guided by Saunders, Lewis, & Thornhill, (2019), which is illustrated in Figure 3.1 below. The research onion below illustrates the key decisions made during the research as layers, with the abstract philosophical decisions in the outer layer leading towards the more practical data collection and analysis decisions in the inner layers. The discussion in this chapter will start with the outer layers and work inwards.

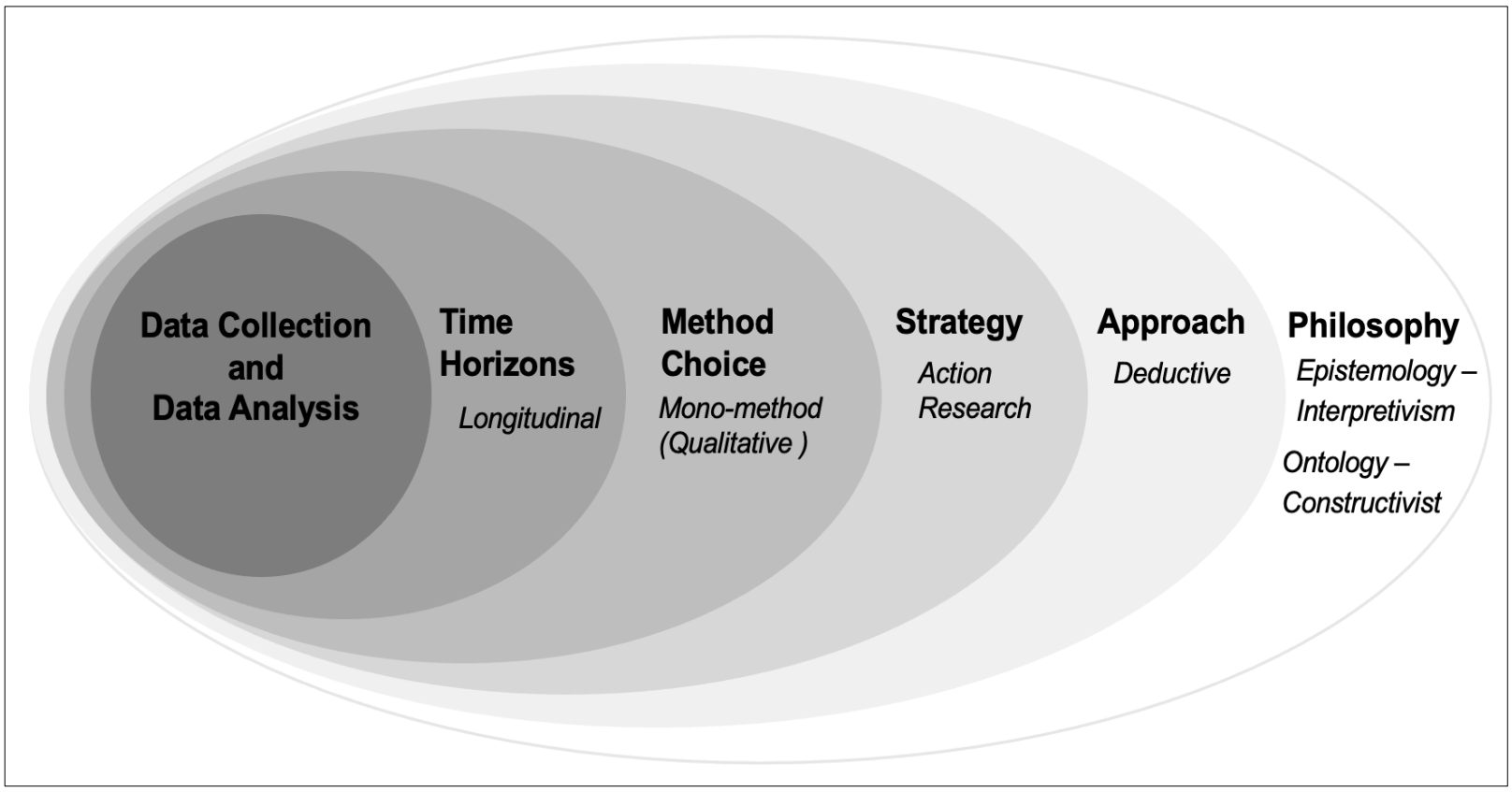


Figure 3-1 Research Onion of this particular study

(adapted by Saunders et al., 2019)

3.2 RESEARCH QUESTIONS

The main research question that drove this study was:

How can coding and robotics support the development of 21st century skills in Early Childhood Education?

In order to answer this, the following sub-questions were asked:

- SRQ1: How can 21st century skills be developed through coding and robotics in early childhood education?

- SRQ2: How can coding and robotics principles be developed in early childhood activities?
- SRQ3: How can coding and robotics activities be designed to best support development in early childhood education?

3.3 RESEARCH PHILOSOPHY: INTERPRETIVISM

This research philosophy is made up of two factors, the epistemology, and the ontology of the study. The ontology of the study refers to the nature of the study's reality (Saunders, Lewis, & Thornhill, 2019). In this study, the ontology was constructivism. This implies that the realities discovered in the study are products of the experiences of groups or individuals participating in the study (Cupchik, 2001). In this study, it was believed that the realities of the phenomenon under study would be discovered through the implementation, observation, and evaluation of the five different lessons. The researcher, participants, and critical reviewer were all viewed as members who impacted the reality of the study as they were all role-players in the constructed experiences.

Epistemology is concerned with the nature of the knowledge and the methods that were used in gaining it. Cohen, Manion and Morrison (2007) regard epistemology as the assumptions that form the basis of knowledge, and how it is acquired and further communicated with other individuals. In this study, the chosen epistemology, as seen in Figure 3.1 above, was interpretivism. Interpretivism not only studies the absence or presence of a relationship between elements, but also the precise manner in which it is manifested and the context in which these relationships occur (Lin, 1998). Interpretivism is relevant to this study as the study sought to gain insight into how coding and robotics support the development of 21st century skills in early childhood education. This is done by interpreting these said realities. Therefore, this study adopted an interpretivist philosophy. An interpretivist philosophy focuses on understanding reality, and posits that this reality is subjective to individuals and their own experiences (Thanh & Thanh, 2015). This was deemed an appropriate philosophy for this study as it focused on the planned coding and robotics activities in which early childhood learners participate, and understanding how 21st century

skills are being developed. These activities are subjective to the particular early childhood learners who participated in this study.

3.4 RESEARCH APPROACH: DEDUCTIVE

The approach of this study was deductive. A deductive research approach is defined in the literature as the reasoning for a study, which is derived logically from a set of previously investigated studies. This results in the conclusion being true when all the previous findings are true (Saunders et al., 2019). This study adopted this belief as the focus was on investigating the relationships between previously investigated concepts of coding and robotics in early childhood education and the development of 21st century thinking skills. This study investigated the relationships that formed between these previously investigated concepts, while taking away the key guidelines that were discovered in the implementation of these concepts in the lessons presented. This was done while investigating existing concepts in a specific South African context. Therefore the vantage point of this study is deductive, however when addressing each theme it is inductive as it aids in the generation of new knowledge for teachers to apply in their lessons.

3.5 RESEARCH STRATEGY: ACTION RESEARCH

The research strategy chosen for this study was an action research design. Action research is defined as a “set of approaches which, at the same time, systematically investigate a given social situation and promote democratic change and collaborative participation” (Brown & Coombe, 2015, p. 187). In education-based research, action research is primarily a “strategy for the development of teachers as researchers so that they can use their research to improve their teaching and thus their students’ learning” (Tripp, 2005, p. 2). This aligns with the core desire of the study, to examine both the design of coding and robotics activities, as well as how coding and robotic activities develop 21st century skills in early childhood education. This study presents several planned coding and robotic activities that place an emphasis on the development of 21st century skills. Throughout the study, the participating early childhood learners engaged in these activities. An action research design is a “non-linear pattern of planning, acting, observing, and reflecting on the changes in the social situations” (Noffke & Stevenson, 1995, p. 2). As seen in Figure

3.2 below, each activity is a cycle of its own - a pattern of planning the activity, completing the activity, observing the learners during the activity, then reflecting on the activity and creating a set of reflections. These revised reflections were then implemented in the planning of the next cycle/activity. This was a continuous cycle that continues until after the fifth activity. Thus, taking the consecutive observations and reflection into consideration, the researcher was able to establish guidelines from the collective activities that would aid in the development of 21st century skills in early childhood learners during coding and robotics activities.

The advantage of adopting an action research strategy is that the study is centered around action, collaboration between individuals, and the generation of different plans, which are raised and reimplemented numerous times (Maree, 2018). This was highlighted in this study as the lessons were planned, implemented, observed, and evaluated five times. The findings were then re-evaluated again by the researcher and the critical reviewer. This allowed for multiple scenarios for reflections to be examined and critiqued. The possibility of ignoring certain social relationships in a study is often a challenge that researchers face when implementing an action research strategy (Maree, 2018). However, this was addressed in this study as it involved a critical reviewer in all five cycles, as well as when evaluating the final findings. The study also focused on the participants' homeroom teachers to investigate whether they had noticed any changes in the participants. Therefore, the study ensured that this challenge was addressed by incorporating multiple individuals who had a role in the study or had a significant relationship with the participants involved in the study.

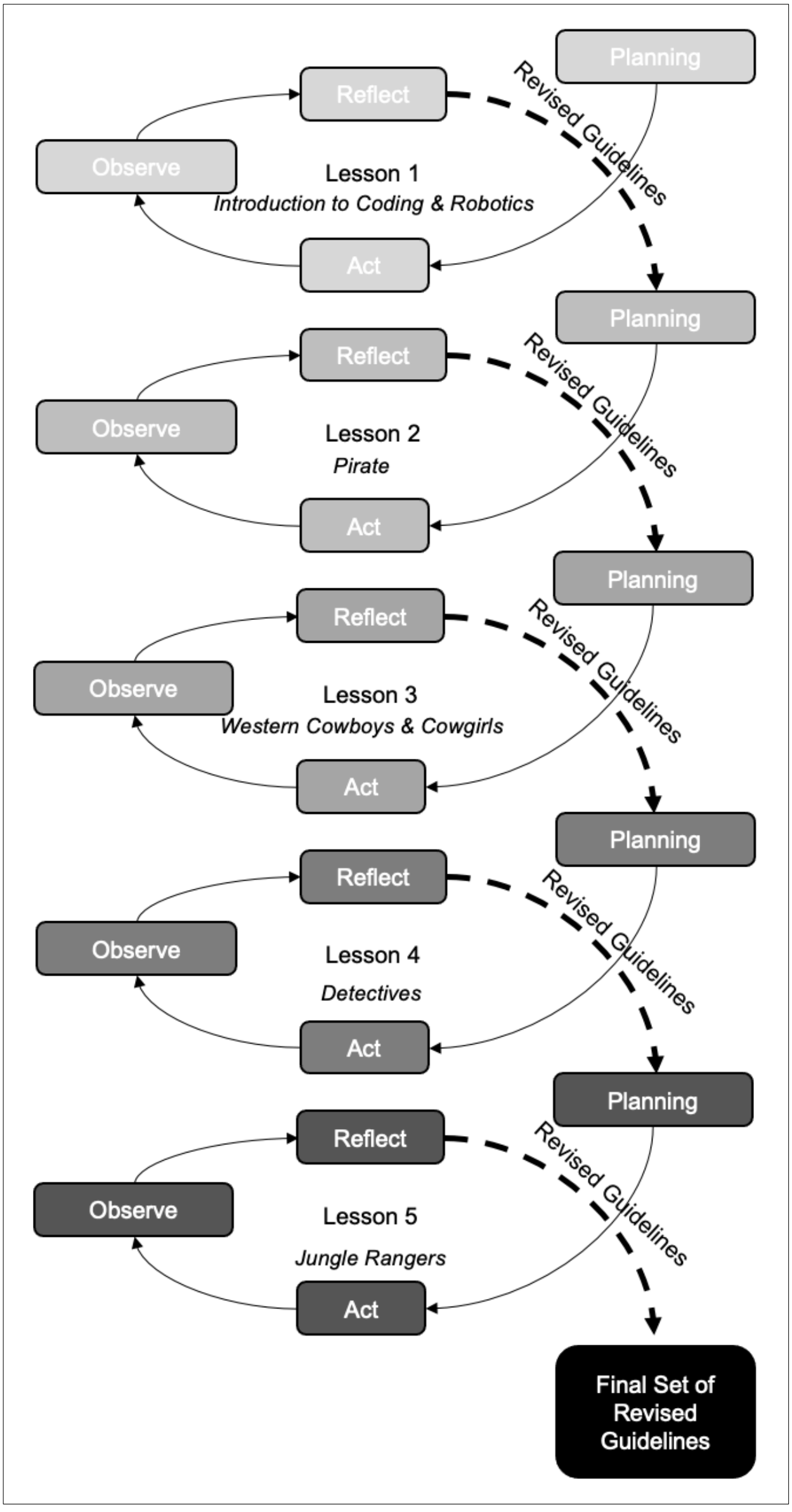


Figure 3-2: The research design of this study

3.6 RESEARCH CHOICE: QUALITATIVE RESEARCH METHODOLOGY

In order to support the interpretivist philosophy that was chosen for this study, the methodology approach chosen was qualitative. In this study, it was maintained that knowledge is interpreted and constructed through interaction and experience. Thus, a qualitative methodology allowed the researcher to focus on the participating individuals' own experiences. Qualitative research is believed to focus on "developing explanations of social phenomena" (Hancock, Ockleford, & Windridge, 2009, p. 6). Adopting a qualitative research methodology in this study allowed the researcher to gather detailed data that focused on the participants' "feelings, opinions, and experiences" (Rahman, 2016, p. 104). While this study investigated how 21st century skills are being developed through coding and robotic activities for early childhood learners. Using a qualitative research methodology allowed the study and analysis of the activities first-hand, as well as receiving information from key role-players in the learners' life. The concluding findings are not based on numerical evidence, however the homeroom teacher feedback interviews are conducted with a numerical rating, however this qualitative data is used to support the quantitative findings and overall conclusion of the study. Interpretivism focuses on the ability to construct understanding (Maree, 2018). This fit the purpose of this study, which was to construct a set of guidelines for coding and robotic activities to ensure the development of 21st century skills in early childhood learners.

3.7 TIME HORIZON: LONGITUDINAL DESIGN

The time horizon in this study was a longitudinal design. A longitudinal design is identified by the collection of data on multiple occasions; this can extend over a period of time (Bryman, 2012). With regard to this study, the data were collected and evaluated over five lessons, which was then analysed and evaluated as a whole at the end. Therefore, the data captured linked to the longitudinal design as the data were collected on five occasions with the same participants, and the same variables being investigated.

3.8 DATA COLLECTION

In this study, the relevant data were collected through semi-structured interviews and observation. The reason for this was due to the study taking a qualitative approach. A semi-structured interview is defined as a type of qualitative method of inquiry that consists of a set of predetermined, open-ended questions that provide the interviewer with an opportunity to gain a deeper understanding of a particular theme (Maree, 2018). The significance of using a semi-structured interview in this study was that it allowed the researcher to gain a deeper understanding of the development of 21st century skills from the participants' homeroom teachers. There were a set of open-ended questions that investigated the teachers' own opinions and practices regarding the development of 21st century skills in the young learners selected to participate in this study. Due to the interview being semi-structured, the participants were free to discuss what they believed was applicable. As seen in Table 3.1 below, interviews were conducted with two Grade R teachers before and after the five planned activities (see Appendix A for the designed interview schedule).

Data were also gathered through observation. The process of observation is defined as the recording of behavioural patterns of participants and occurrences without essentially questioning or communicating with the participants themselves (Maree, 2018). The role of the researcher is to observe the activities and evaluate the activities presented. In this study, the researcher observed the participants, the learners, during the planned activities. The findings from the observations were kept in a photo journal, as well as being detailed in observation sheets that the researcher completed after each activity was concluded (see Appendix D and E for the photo journal and the activity observation sheet). The photo journal provided images of the activities that took place, as well as short descriptions. The observation sheets gave a short description of what occurred in the lesson, as well as highlighting key words, which aided in the analysis of the data.

The data collection strategy aligned with the qualitative approach of the study as it focused on the direct interaction with the participants (Gill, Stewart, Treasure, & Chadwick, 2008). In this study, the researcher took on the role of the activity designer, as well as the facilitator in the implementation of the activities. The

researcher planned five activities that focused on the TPACK elements. The researcher incorporated the necessary 21st century skills in the planning of the activities, and ensured that the relevant early childhood pedagogy and coding and robotics technology were incorporated. A critical reviewer was present during each lesson to help teach, facilitate, and observe. Both the researcher and the critical reviewer assisted the learners in each activity as they were carried out.

Table 3.1: Data collection strategies

21st century skills developed in early childhood learners through coding and robotics				
Research question	**Main Content**	**Data Collection**	**Why?**	**Participants**
1	How can 21st century skills be developed through coding and robotics in early childhood education?	TPACK: Conceptual framework Each activity	Observation photo journal	Context Design	The researcher also designed the activities, as well as facilitating during the activities and taking a role as a facilitator. Early childhood learners were involved in observation.
2	How can coding and robotics principles be developed in early childhood activities?	TPACK & 21st thinking skills. Pre-intervention 21st century skills interview with two homeroom teachers. Five coding and robotics activities. Post-intervention 21st century skill interview with two homeroom teachers.	Homeroom teacher interviews and observation photo journal.	Analysis of skills and activities.	When designing the activity, the researcher paid close attention to the incorporation of the necessary skills in the activity. Interviews with the two Grade R teachers, whose learners were participants in the study. There were two interviews: before activity implementation and after activity implementation. The interviews were based on the individual learners.

3	How can coding and robotics activities be set up to best support development in early childhood education?	Evaluation of activities.	Observation photo journal.	Analysis of skills and activities.	The researcher evaluated each activity after they were completed.

3.9 DATA ANALYSIS

Data analysis is a process of analytically and logically interpreting the data that are collected through the course of the study to determine certain patterns and relationships that occur in the identified themes (Maree, 2018). In this study, the researcher analysed the photo journal, the activity observation sheets, and the teacher interviews in order to gain a deeper understanding of the themes that emerged. Content analysis is defined as a research method that allows for qualitative data to be collected and interpreted according to themes or categories that are relevant to the researcher (Haggarty, 1996). This data analysis method helped in analysing the data received in this study, focusing on the relationship between coding and robotics in early childhood and the development of 21st century skills. This was done to develop guidelines to aid teachers in planning coding and robotic activities that help support the development of 21st century skills. The study engaged in three different levels of analysis.

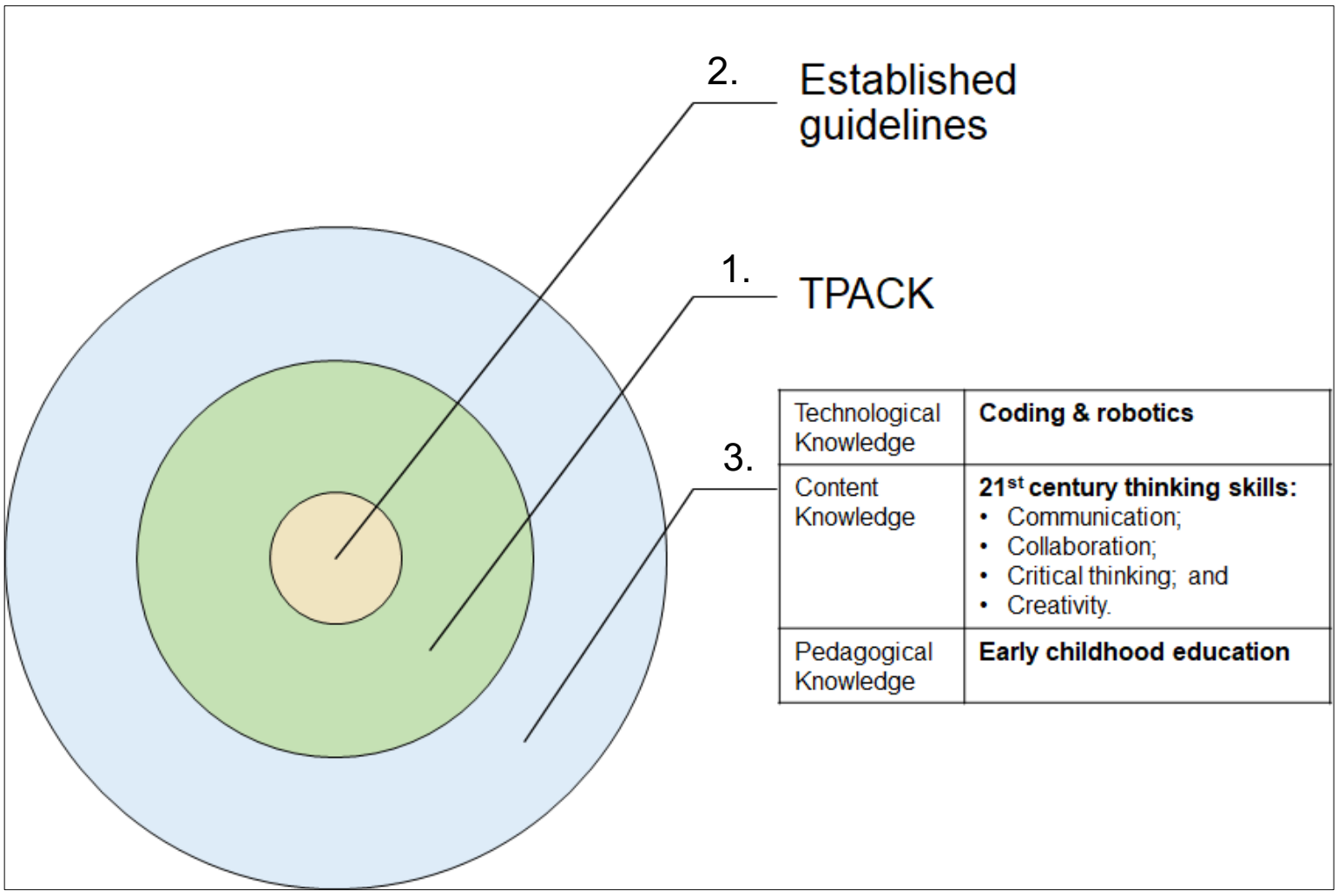


Figure 3-3: The relevant core concepts that were investigated in this study

- Level 1- *core concepts* were identified from the research questions and the application of the TPACK model. These core concepts comprised 21st century thinking skills, and coding and robotics, and early childhood education. As seen in Figure 3.3 above, this study focused on the core concepts of Technological Knowledge (TK), Content Knowledge (CK), Pedagogical Knowledge (PK).
- Level 2- *key aspects* were identified from the observation and evaluation of the lessons. These key aspects are noted and further investigated in Chapter 5. The key aspects are discovered as the data from the lessons in completed. Each domain of the TPACK framework will gain their own key aspects.
- Level 3- this comprised a deeper level of analysis as the researcher identified themes. The themes found in Chapter 5 and 6 combine similar key aspects to create a broader recurring theme. This level of analysis ais in the development of the guidelines to assist teacher in the planning of coding and robotic activities to develop early childhood learners' 21st century skills.

3.10 POPULATION AND SAMPLING

In qualitative research, sampling focuses on selecting a small number of important participants to generate the most information and have the greatest influence on the development of relevant knowledge (Patton, 2015). By sampling the population, the researcher can lessen the amount of time, the amount of money spent on the study, and the workload involved (Gattermann, 2015). This study applied non-probability sampling, particularly, convenience non-probability sampling. Non-probability sampling focuses on the subjective procedures used to select participants, instead of randomisation (Etikan, Musa, & Alkassim, 2016). The sample chosen for this study comprised six early childhood learners who were regular participants in a coding and robotics club, as well as their homeroom teachers. The homeroom teachers were the dedicated teachers who were always with this specific group of learners. In Grade R, these are the teachers who teach the majority of the Grade R curriculum to the learners. The learners and teachers were located at an affluent school in Johannesburg, South Africa that had recently introduced coding and robotics as an extra-curricular activity. The learners ranged from the ages of five to six years old. Non-probability sampling can be sub-divided into either convenience sampling or purposive sampling (Maree, 2018). This study consists of both convenience and purposive sampling. Convenience sampling is described as a type of non-probability sampling in which the participants of the target population are selected for the sample as they meet a practical criterion such as: accessibility to the researcher; geographical nearness of the researcher, and willingness of the participants (Etikan et al., 2016). In this study, the participants were selected using convenience sampling as the sample was easily accessible and in proximal location to the researcher. As the sample selected were learners and teachers at the same school where the researcher worked, therefore providing easier access. This study used a purposive sampling technique as the participants were chosen based on a set of characteristics. A purposive sample is defined as the measured selection of participants due to the qualities that each participant possesses (Etikan et al., 2016). The sampling was also purposive as the participants were required to be early childhood learners and teachers of the selected early childhood learners who participated in the coding and robotic lessons.

3.11 LIMITATIONS

There were two key limitations in this study that could be addressed in future research, the first being the small sample size. This study only had six participants. Due to the COVID-19 pandemic, there were very few children who returned to school instead of doing online schooling. This allowed the researcher to select the few that did physically attend school. In order to ensure a representative distribution of the population, I would recommend that future studies select a larger sample size. The second potential limitation that was found in this study was the lack of available time. The study was conducted over six weeks and consisted of a collection of five activities that allowed the researcher to collect data. However, in order to receive more data, it would be beneficial for future studies to consider collecting data for a longer period of time in order to document a definite change in the participating learners.

3.12 ETHICAL CONSIDERATIONS

This study took into consideration the ethical factors involved in conducting research. This study strictly adhered to the University of Pretoria's ethical guidelines and considerations (Code of Ethics for Research, 2019). Consent is outlined as the participants' voluntary agreement to participate in a study (Shahnazarian, Hagemann, & Aburto, 2009). All of the participants, which comprised learners and teachers, were willing to participate and gave their consent (see Appendix B for the consent forms). The researcher sought consent beforehand from the teachers involved, the parents of the young learners, the school board and principal, as well as assent from the learners. Participation was voluntary, thus before taking part in the study, the researcher made the participants aware of the fact that they could decide to withdraw from the study at any point without consequences.

The researcher further ensured the anonymity of the participants through the use of pseudonyms. Anonymity is described as the concealment of participants' identity so that their personal responses cannot be traced back to them (Fouka & Mantzorou, 2011). In this study, the participants were not anonymous to the researcher as the researcher worked at the selected school, however, the participants' identities are protected through the use of pseudonyms. In this study, a photo journal was kept

for observation, so in order to ensure anonymity, the faces in the photos are blurred to further protect the learners' identity. These aspects highlight the level of confidentiality ensured in this study. All of the participants' private information will be kept reserved and confidential. Confidentiality is a fundamental element in research, and is defined as a guarantee that the data cannot be traced back to the participants through the dissemination of the results and findings (Wiles, Crow, Heath, & Charles, 2019). All of the participants were reassured that their responses would be completely anonymous in the dissemination of the results of this study.

3.13 TRUSTWORTHINESS

This study used Klein and Myers' (1997) Seven Hermeneutic Principles for evaluating the study's trustworthiness. The use of the seven principles aids in the evaluation, credibility, and validity of a particular or intended study (Cardoso & Ramos, 2012). The first principle suggests that the understanding of a complex whole is derived from the preconceptions of its parts; this principle is the fundamental principle of the hermeneutic circle (Klein & Myers, 1999). This study addressed this principle in both the research approach and the theoretical framework that were implemented. The principle of the hermeneutic circle proposes that human understanding is attained by revising the relationship between the interdependent meaning of parts to the whole that they collectively form (Klein & Myers, 1999). This links to the research approach chosen for this study, which was action research. The action research approach requires continuous reflection throughout the study. Noffke and Stevenson (1995) define action research as a non-linear process that involves the concepts of "planning, acting, observing, and reflecting on the changes in social situations" (p. 2). In this study in particular, each lesson went through the process of revision in order to assist in the planning of the consecutive lesson, as seen in Figure 3.1. Thus, the study aimed to revise the different concepts under investigation in each presented lesson. This relates to the theoretical framework chosen for this study as the TPACK framework highlights the importance of understanding the relationships between the different concepts, such as technology, content, and pedagogy (Mishra & Koehler, 2006).

As seen in Figure 3.4 below, the TPACK framework was implemented throughout the study. Each domain that contributes to the construction of the TPACK was aimed

at answering the sub-questions posed in this study. In the figure below, the lesson cycle (which is shown in the figure by the smaller circle on the right) represents the research design of action research. The researcher repeated that cycle a total of five times as the five lessons were completed. Each lesson consisted of the planning, acting, observing, and revising of each concept being investigated; this was a cyclic process that led into each consecutive lesson. The lesson cycle relates to the hermeneutic circle as each lesson presented in the study addressed each 'part' involved in the study when planning. The 'parts' were then implemented as a 'whole' as the TPACK in the implementation of the study. Thereafter, the TPACK was again broken up into its particular parts when reflecting for the planning of the next lesson. With this being said, all the concepts were analysed as individual parts. However, when understanding the main research question, the concepts are seen as interdependent parts of the TPACK. This is seen on the left side of Figure 3.4.

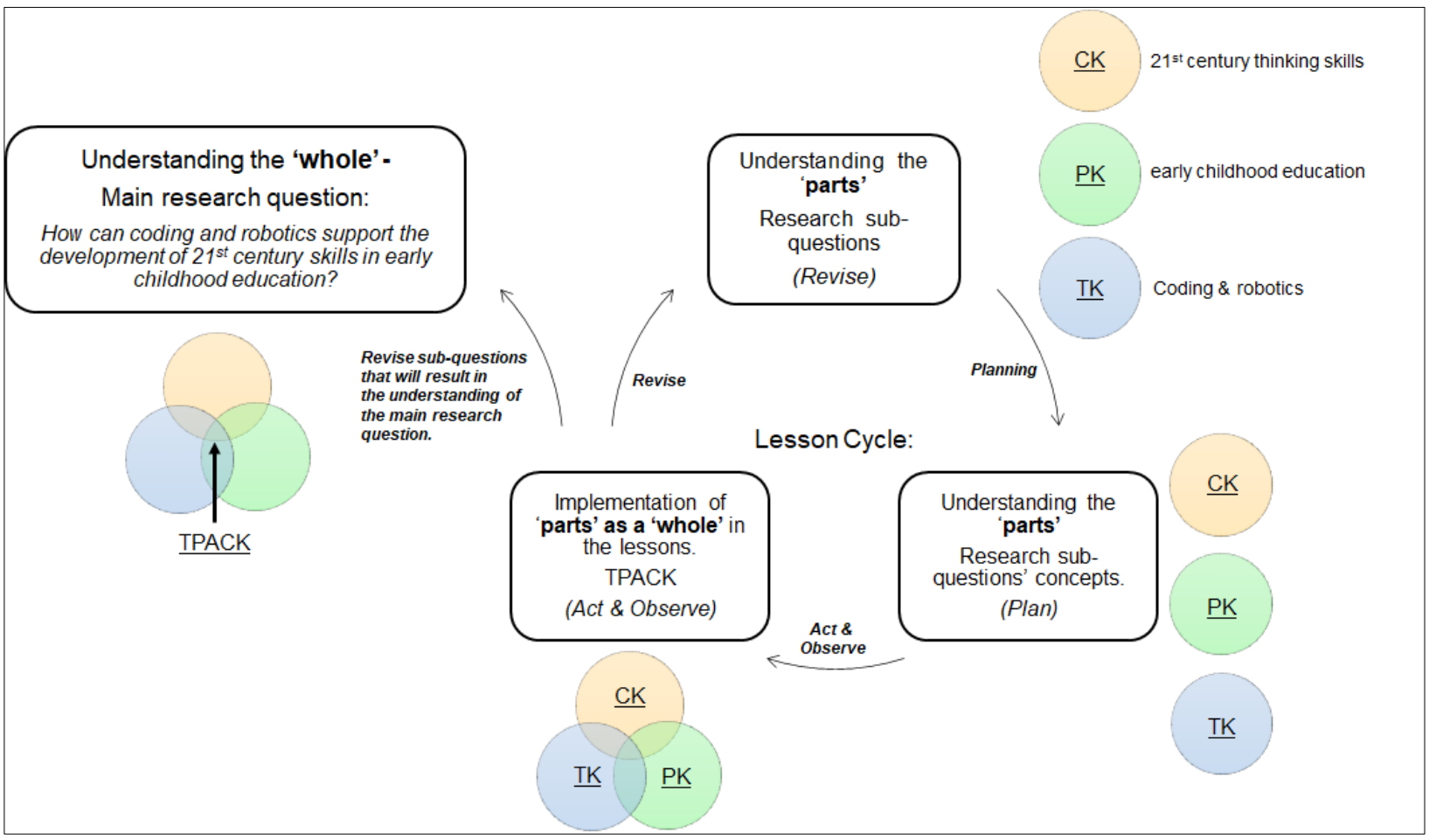


Figure 3-4: Hermeneutic principles for evaluating and ensuring trustworthiness

Klein and Myers (1999) view the principle of the hermeneutic circle as the meta-principle on which the following principles expand. The other six principles are presented in Table 3.2 below. Implementing Klein and Myers' (1999) seven principles for conducting and evaluating interpretive studies assisted the researcher to ensure the trustworthiness of this study. Implementing these principles further

motivated and assisted the researcher to make sure that the results of the study are convincing and plausible. These principles governed the research process throughout the study, resulting in the discovered findings.

Table 3.2: Hermeneutic principles for conducting and evaluating interpretative field studies further discussed

(Klein & Myers, 1999)

	Principle Title	Explanation	Implementation in this particular study
1	The principle of contextualisation	The principal of contextualisation focuses on the social and historical context of the subject matter, thus allowing the intended audience to have a clear understanding of how the current investigation occurred (Klein & Myers, 1999).	The researcher focused on investigating the context in which the study took place. There was substantial research regarding the different concepts discussed in this study. The researcher focused on investigating appropriate early childhood coding and robotic activities. The activities were held in a typical classroom in an affluent school context. However, the lessons incorporated a variety of resources, some being homemade resources that are easily accessible. The study followed an interpretative philosophy, which supports the understanding that the reality constructed in the study is subjective to individuals' experiences (Thanh & Thanh, 2015).
2	The principle of interaction between the researcher and the subjects	This principle focuses on the researcher's ability to place themselves in the subject's historical perspective (Klein & Myers, 1999).	By adopting the interpretivist philosophy, the researcher focused on the social interaction between themself and the participants. The researcher took on an active role as a facilitator, teacher, and researcher while conducting the study. The researcher highlights the social interaction between the participants as they engaged with one another in the lessons. The data collected was socially constructed through the observation and the use of a photo journal.
3	The principle of abstraction and generalisation	The principle of abstraction and generalisation argues that the trustworthiness of the discovered findings relies on the plausibility and cogency of the logical reasoning used in explaining these findings (Klein & Myers, 1999).	This study implemented the principle of abstraction and generalisation as the findings were connected to the theoretical framework employed. Ensuring that the study related to previously valid research and frameworks provides the reader with a better understanding of the reality of the study.

	Principle Title	Explanation	Implementation in this particular study
4	The principle of dialogical reasoning	The principle of dialogical reasoning motivates the researcher to address their own prejudices or preconceptions that directed the research design (Klein & Myers, 1999).	The researcher implemented an action research design. This design encourages a non-linear pattern, which consists of constant reflection on the changes in the social situation (Noffke & Stevenson, 1995). Thus, the researcher repeatedly and constantly reflected after each lesson. This gave the researcher the opportunity to address any preconceptions. During the lessons, there was another teacher who assisted in the presentation and observation of the lesson. This gave the researcher the opportunity to compare her findings and observations with that of the other teacher throughout the study.
5	The principle of multiple interpretations	The principle of multiple interpretations requires the researcher to investigate the effect that the social context has on the study by examining and documenting multiple view-points (Klein & Myers, 1999).	This study addressed this principal as the researcher interviewed both homeroom teachers regarding the development of 21st century skills in the learners. The researcher also worked alongside another teacher in the coding and robotics classroom. This teacher engaged in frequent discussions regarding the study. The teacher contributed to the study with reflection regarding the concluding findings and the discovered guidelines. The researcher was open to the teacher's opinions and criticism. The critical reviewer also played a role in providing another interpretation as the critical reviewer was not only present for the activities, but was also motivated to reflect and discuss with the researcher, as well as critically observe the lessons.
6	The principle of suspicion	The principle of suspicion focuses on the study's sensitivity to any possible biases or distortions in the data collected from the different participants (Klein & Myers, 1999).	The principle of suspicion is addressed in this particular study with regard to the research design. The study focused on collecting data by observing the participants. The observations were captured in a photo journal. This allowed the data captured by the participants to be deemed as sensible as the participants could not display any possible biases in the photographs. The researcher aimed to mitigate her own bias as she took on the roles of designer, facilitator, and researcher.

3.14 CHAPTER 3 SUMMARY

This chapter focused on providing a clear understanding and description of the research methodology of this study and the manner in which it was conducted and analysed. This chapter addressed the various considerations that were taken into consideration in the preparation and implementation of the study. The following chapter will provide the reader with a detailed description of the different lessons that took place in the format of the Action Research (AR) cycles.

CHAPTER 4 RESULTS

4.1 INTRODUCTION

The results of the Action Research (AR) cycles are presented in this chapter. The chapter is structured in terms of the five AR cycles, each linked to one of the coding and robotics lessons. Furthermore, each of these cycles are discussed in terms of the core concepts of the TPACK framework and the sub-research questions. The link between the framework and the sub-research questions is depicted in Figure 4.1.

Throughout this chapter, the colours in Figure 4.1 are used to represent each of the research questions/core concepts being addressed. Sub-research Question 1 focuses on the 21st century skills as content knowledge, which are represented by the colour green. Sub-research question 2 focuses on coding and robotics as technology knowledge, which is represented by the colour blue. Sub-research Question 3 focuses on the relevant pedagogical knowledge within early childhood education, which was represented by a pale orange.

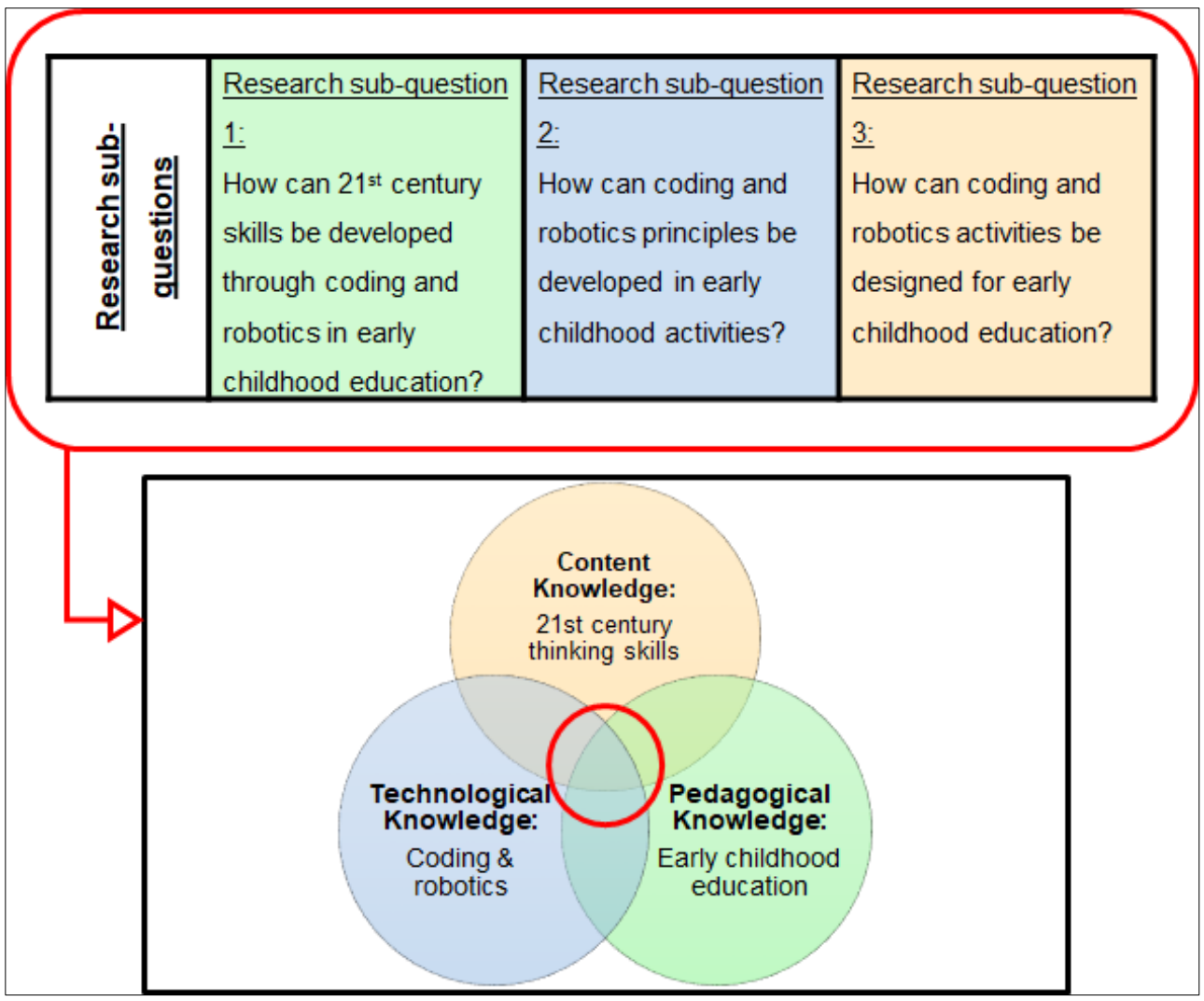
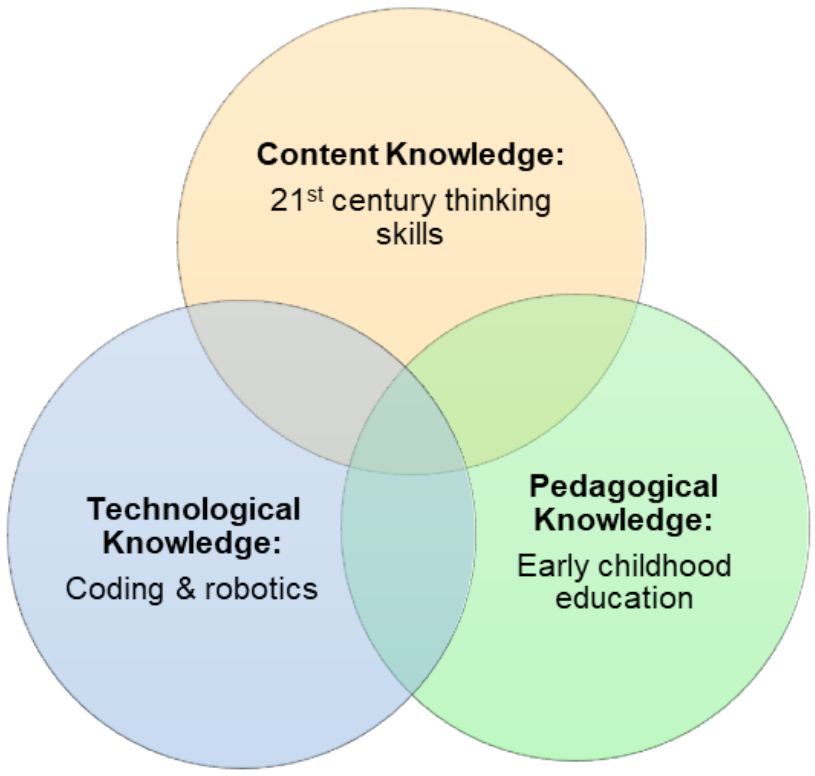


Figure 4-1: Core concepts of this study

Each of the TPACK core concepts played a significant role in the lessons that were presented to the early childhood learners. Figure 4.2 provides a brief summary of this information.

The content knowledge that was implemented in each lesson related to the 21st century skills investigated in this study. The skills are; communication, collaboration, critical thinking, and creativity. These skills are represented differently in each of the lessons presented to the learners.



The technological knowledge in this study increased in difficulty as the learners became more comfortable with the technological knowledge presented to them.

The pedagogical knowledge in this study looked at the theory of constructionism when designing lessons for early childhood education. However, this element developed exponentially as each lesson is completed. The researcher developed her findings after each lesson and reflected on the findings when planning the next lesson.

Figure 4-2: Roles of the particular TPACK core concepts in this study

In this chapter, each AR cycle is discussed in terms of the AR process. The discussion commences with the planning of the lesson (plan), continues with the observation of the execution of the lesson (act/observe), and concludes with a

reflection. The aspects identified in the reflections impacted the planning of the next cycle. This was a continuous process that flowed into the consecutive cycles. During the implementation of the lessons the researcher worked alongside a teacher participant, who will later contribute her own observations.

Plan: the planning of each lesson is described, illustrated by photos where applicable, and linked to the relevant TPACK color-coded concepts (see Appendix C for the full lesson plans).

Act and Observe: the full photo journal captured for this study is available in Appendix D, while the complete lesson observations are available in Appendix E. The results of the analysis of the observations are presented in these discussions in a table format. The table focusing on 21st century skills development depicts the specific skills observed in the first column, followed by a summary of where in the lesson it was included, emerging key aspects identified during the analysis (in bold), and lastly a short discussion of the codes. The coding and robotics concept development results are depicted in the relevant table, also indicating the emerging codes (in bold) and a brief description.

Reflect: the reflection section provides the code identified during each cycle and a short description thereof.

The lessons planned and presented in this study considered the affordability of the lessons, in order for the lessons to be relevant to the many South African schools who have limited finances or resources to contribute to the lessons. Therefore each lesson has a combination of activities, some including the use of the robot and LEGO, as well as activities that were designed with accessible resources, such as paper, cardboard, and toy figurines. The robots used in the different lessons were a mid-range priced robot, available for R650. The Coding Critter, can be bought from multiple companies, therefore their price may vary.

4.1.1 Lesson 1

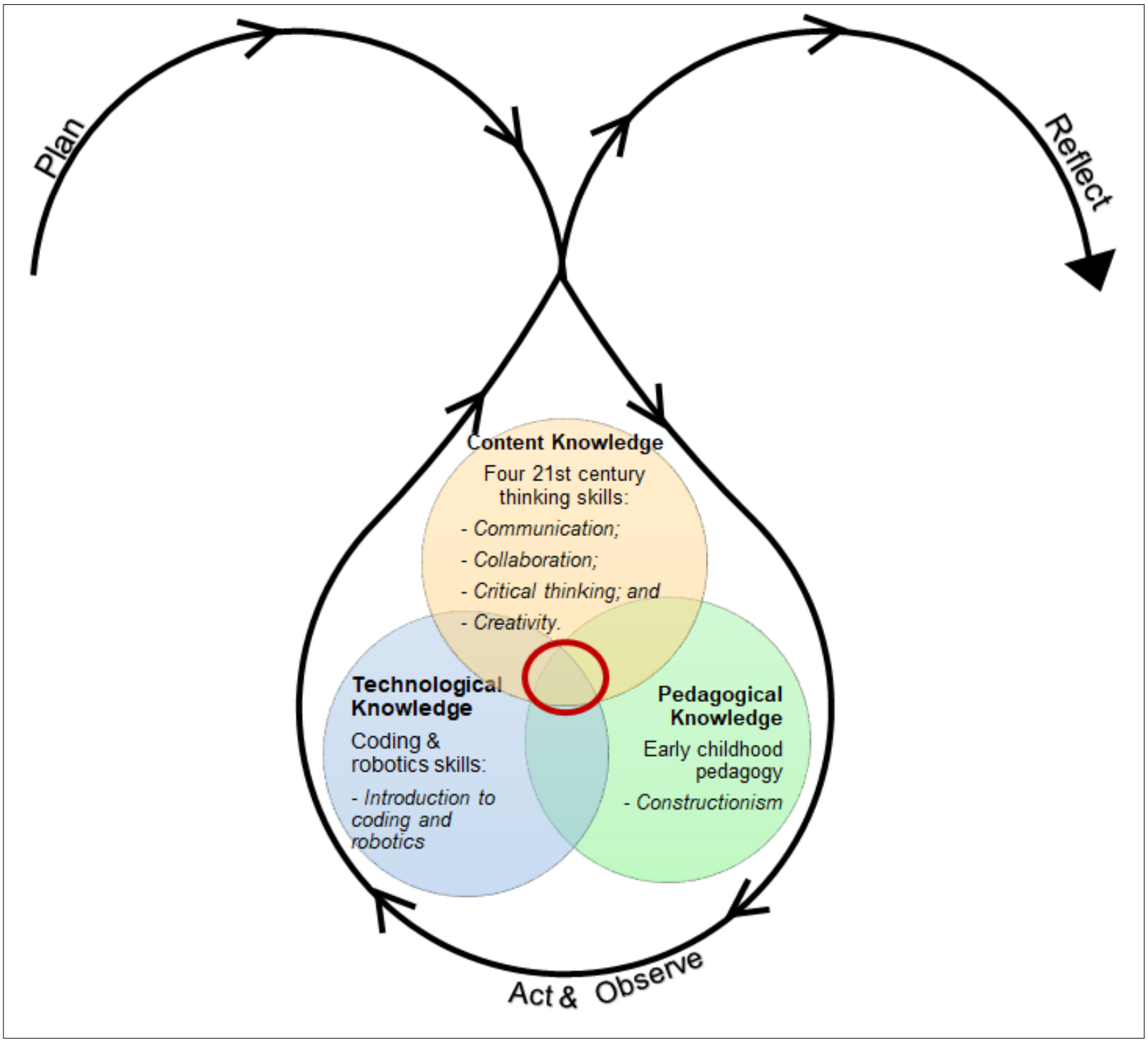


Figure 4-3: Lesson 1 Action Research process and TPACK

Figure 4.3 provides a summarised illustration of the current lesson cycle.

4.1.1.1 Plan

The first lesson was planned as an introduction lesson and was based on the TPACK framework. The lesson was thirty minutes long, which was divided into a five-minute introduction, three activities of five minutes each, and a five-minute conclusion. The spare minutes were used in between for the children to move stations and sanitise between each station. The topic of the lesson was the introduction to coding and robotics.

The lesson was planned to introduce the learners to coding and robotics tools and concepts appropriate to their age. The lesson aimed to address a few technological skills regarding coding and robotics. Each activity in the lesson planned to focus on one or more 21st century skill. As the learners were still young, the lesson was planned using constructivist pedagogy, which focused on the learners constructing their own understanding through their experiences.

The technological knowledge that was planned for this activity was as follows:

- Understanding the roles and responsibilities of coding and robotics class;
- How to care for the robots;
- A basic understanding of what the robot can do;
- Direction (forward, backwards, left, right);
- Understanding of a grid - one block equates to one step/action;
- Understanding that arrows show direction;
- How to use a sequence strip.

The introduction of the lesson focused on the children gaining an understanding of simple instructions and direction. The learners stood along a line that was taped to the floor while the researcher called out direction instructions. The instructions started as simple (forward, backwards, left, right), they were then combined in pairs (e.g. forward *and* right). The lesson was then divided into three activities. These activities aimed to address the different 21st century skills. The children were divided into pairs and one group of three when moving between the different activities. The learners spent five minutes completing each activity. The three activities are explained in detail below:

1. The researcher created a grid using square blocks of white paper. Plastic snake figurines were placed randomly on the grid, as seen in the Figure 4.4 below. The children took turns - one child was an instructor and the other was a collector. The instructor would stand and instruct the other child where to move in order to collect the animals as fast as they could. The collector would listen to the instructor and move around the grid with a bucket, collecting the animal figurines.

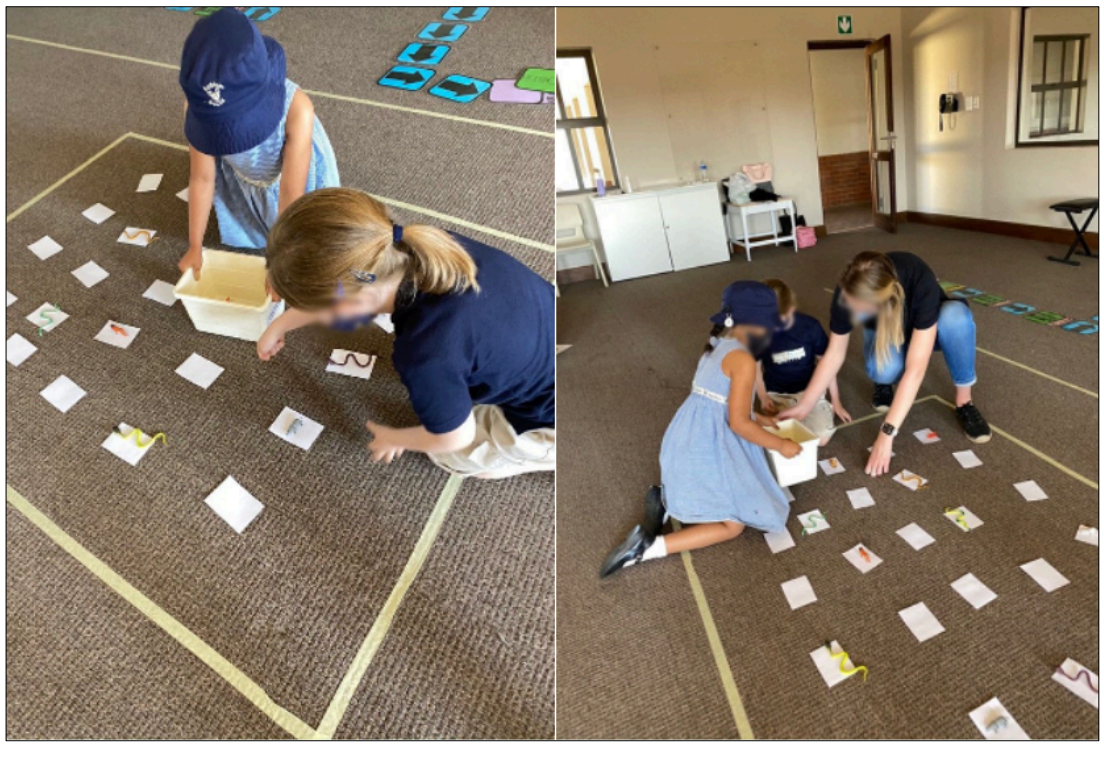


Figure 4-4: Lesson 1 photos about Activity 1

This activity aimed to develop 21st century skills, communication, critical thinking, and collaboration

2. The learners were given Coding Critters. The children were given different sequencing strips through which they were required to work. There was very little instruction given by the researcher. The children had to discover how to make the Coding Critters move. The children took turns solving the different sequences, and were then encouraged to create their own sequences. One child would use the arrow cards to plan their own sequence and the other child would use the coding critter to act out the planned sequence. The children took turns in each role. Figure 4.5 below shows the different sequence strips that were given.

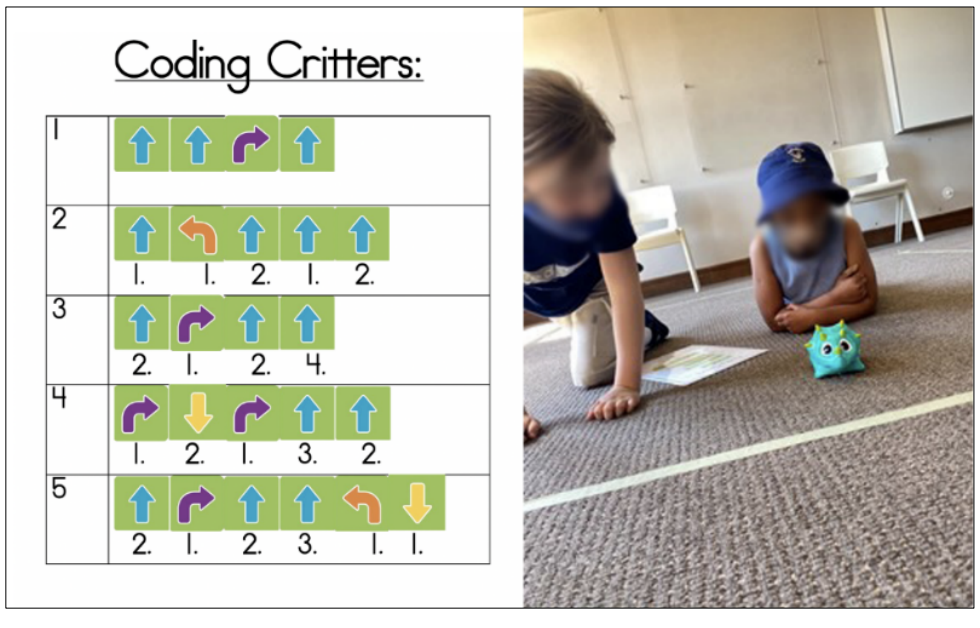


Figure 4-5: Lesson 1 photos about the introduction to Coding Critters

This activity aimed to develop the 21st century skills of communication, collaboration, and creativity.

3. The children were given floor tiles that were designed for them to follow. It is a fun activity, similar to hopscotch. The children were then able to design their own floor tile sequence for their friends to follow. The floor tiles had a start and stop tile, arrow tiles, as well as action tiles that needed to be completed. Figure 4.6 presents an example of these tiles.

Figure 4-6: Lesson 1 Activity 3 – photograph of the floor tiles

This activity aimed to develop the 21st century skills of creativity and collaboration.

The conclusion of the lesson focused on the learners' understanding of coding grids, as depicted in Figure 4.7 below. The researcher explained the concept of a coding grid, whereafter each child was given a grid and their own pencil. Along with the researcher's guidance and each other's guidance, the learners were encouraged to draw arrows to solve the different grid stories. The children had to get the dog to the kennel without touching the shaded blocks. The researcher guided the learners, getting them comfortable with the task and what would be expected future tasks. This activity was allotted five minutes.

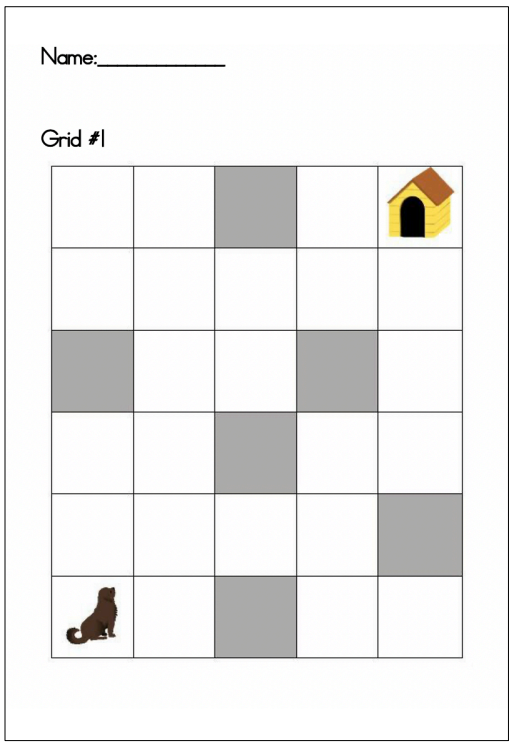


Figure 4-7: An image of the grid that was used in Lesson 1

4.1.1.2 Act and Observation

Table 4.1 depicts a summary of the 21st century skills development as observed during the first lesson. The observation schedule for this particular lesson can be found in Appendix E. The first column in Table 4.1 below states the 21st century skill being addressed. The second column presents the activity, indicating which 21st century skill each activity planned to achieve. The second last column displays how the application of the skills was planned, and the final column provides a brief discussion.

Table 4.1: SRQ 3- Lesson 1 - 21st century skills development results

Lesson 1: 21st century skills Development					
21st Century Skill	**Activity**			**How skill was planned**	**Discussion**
	1	**2**	**3**		
Communication				The teacher/researcher as a **facilitator.**	Due to the researchers/teacher's role being more as that of a facilitator, it *encouraged the learners to communicate* with one another before asking for assistance.
				In the first activity the learners had to focus on communication as they had to **guide their friend on where to go**.	In the first activity, poor communication skills were easily identified when learners struggled to guide their friends. Simultaneously, great Communication skills were identified when the learners could guide their partner with ease.
				The second activity focused on developing the learners' communication skills as the **learners were encouraged to discuss** coding and robotics.	The learners discussed how the Coding Critter moves and how to follow the sequences correctly. The learners were encouraged to help one another to gain a better understanding while explaining how Coding Critters move. This led to them guiding their partner to complete their own sequence when discovering how a Coding Critter works.
Collaboration				In the first activity, the learners had to **think and plan a course that their partner had to follow.**	In all the activities, the learners shared ideas and built on each other's understanding. In the first activity, the learners discussed trying to solve the quickest route to get all the snake figurines. This encouraged the learners to consider one another's ideas and combine each opinion.
				For the second activity, the children **worked in groups** to get the Coding Critter to **complete different sequence strips** and then to **create and complete their own sequence strips.**	The second activity got the learners to help one another to code the Coding Critter to follow a sequence strip. The learners helped one another, they watched each other to see whether they were doing it correctly, and then assisting if they needed help. The learners also worked together to build their own sequence strip and to follow it. The learners seemed to work together when both creating the new sequence strip and following the new sequence strip.
				The third activity encouraged the children to **create their own gross-motor sequence.**	For the third activity, the learners worked together to build the floor sequence plan. They were running back and forth building the sequence and correcting one another when a tile was placed skew or incorrectly. The learners

			tried to make it as interesting and fun as possible.
Critical thinking	×	The **researcher/teacher as a facilitator**. Through **exploration and discovery** of new activities.	The researcher/teacher took a facilitating role in the classroom, encouraging the learners to think for themselves. During the first activity, the learners had to explore and discover. This was new to the learners, and it encouraged them to think critically and find their own solutions. The learners developed their critical thinking skills as they were encouraged to design their own sequence in order to collect the snake figurines as quick as possible. The learners kept reminding themselves to find the quickest route and often corrected one another when they felt they could think of a shorter route.
Creativity	×	Learners **encouraged to design unique solutions.**	All the activities encouraged some sense of creativity as the learners had to design their own sequences in order to complete the task. The learners were enthusiastic and confident in working on their own and had their own authority to design and make their own decisions regarding the sequence they wanted to design.

The four 21st century skills focused on in this study were observed throughout this lesson. Communication was consciously planned in the first two activities, collaboration in all three activities, and critical thinking and creativity in one activity each. The main observations in this lesson were: the important role of the researcher/teacher as a facilitator to ensure that the learners worked as individuals and communicated with each other; the designing of activities to ensure that the learners learned to collaborate, guide, and support each other; the designing of the learning environment to foster critical thinking; and creating opportunities for creativity.

Table 4.2 summarises the development of coding and robotics principles during Lesson 1.

Table 4.2: SRQ 2- Lesson 1 - coding and robotics development results

Coding and robotics development in activities
• Understanding the **roles and responsibilities of coding and robotics class** - this was discussed in the introduction to the lesson. Each activity also started to highlight the use of sequences, and planning before acting, which is an element of coding and robotics.
• How to **care for the robots** - this was discussed in Activity 2 when the children were working with the Coding Critters. It was crucial for the researcher to explain the care required in order to ensure that the robots did not break due to misuse.
• Basic understanding of **what the robot can do** - this was demonstrated in Activity 2 through the learner's own experiences as they were encouraged to complete different sequences that allowed them to **use all the buttons** present on the Coding Critter. The learner was then allowed to experiment when creating their own sequences.
• Direction (forward, backwards, left, right) - this was highlighted in every activity. The introduction was more by the researcher, and allowed the children to grasp the *terminology* that would be used in order to define direction. However, the children did need some assistance at times as when they were excited, they would often just point in a hurry and ask their partner to move there instead of defining left or right, for example. However, the teacher kept assisting and gently reminding the learners to use the correct direction terminology.
• **Understanding of a grid** - one block equates to one step/action- this was demonstrated and explained to the collective class during the conclusion. The learners got to engage with the researcher/teacher and each other, and discuss the grid and the ways in which to represent a sequence on the grid regarding arrows.
• Understanding that **arrows show direction** - this was again demonstrated in the conclusion when the learners were encouraged to draw their own arrows, but also in the third activity as the learners used sequence tiles with arrows on in order to show direction.
• How to use a **sequence strip** - this was shown in the second activity as the learners were given a collection of sequence strips and then were encouraged to create their own. The children gained their understanding through experiences and refrained from asking the researcher questions, instead they were encouraged to talk to one another.

During this lesson, the aspects observed were: basic robot care and actions, as well as the applications of sequences, directions, grids, and arrows.

4.1.1.3 Reflect

The reflection results for Cycle 1 are stated in Table 4.3.

Table 4.3: SRQ1- Lesson 1 reflections

	Lesson	End of AR Cycle 1 reflections
Key aspects addressed throughout the study	**1**	• Dedicate time for the learners to engage in **discussions** about the activity - the children were eager to move between different activities without having a calm discussion regarding the current activity they were completing. This is believed to be better achieved with the use of a timer. • Allowing the children to **work in pairs** encouraged them to continue to communicate and collaborate on the task at hand. The **activities were learner-centred**; this was implemented in this activity and was successful as the learners communicated their opinions and allowed the researcher to take a more facilitating role in the classroom. Due to COVID-19 protocol, allowing the children to work in pairs allowed for sanitising between stations to be a lot easier to manage between the different activities. • **Time** – the children were rushed to complete activities that they were excited about and went over time at certain stations. In this reflection, we found it important to give the children time to play and explore regardless of the activity at hand. Therefore, it was important to set aside a few minutes before or after each activity to allow the children to play with the apparatus and tools at that activity station, and sanitise the station before moving onto the next one. • The children were more comfortable following a floor tile instruction than creating their own. Include more **creativity-led activities** in future - we believe that at the children were not comfortable designing their own floor tiles and preferred to be given instructions to follow. We believe it was important to provide the learners with even more opportunities to be creative.

The most significant reflections at the end of Cycle 1 included the importance of discussion time for learners; the value of learner-centered and collaborative activities; the management of time during the lesson; and the need to design more creativity-led activities.

4.1.2 Lesson 2

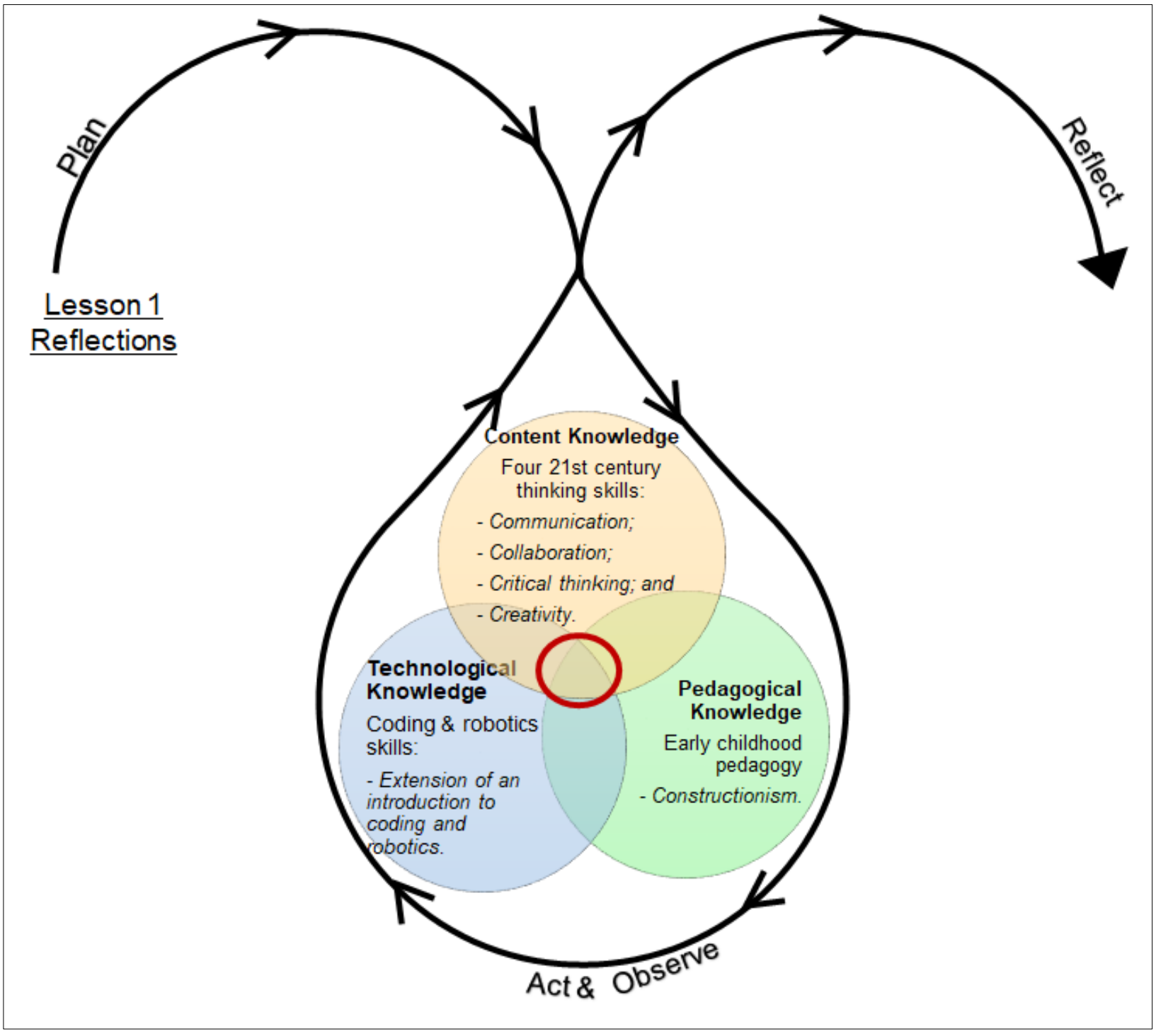


Figure 4-8: Lesson 2 - Action Research process and TPACK

Figure 4.8 provides a summarised illustration of the current lesson cycle.

4.1.2.1 Plan

The lesson was decided to run according to a theme, which for this lesson was pirates. The lesson was planned to be thirty minutes long, which was divided into a five-minute introduction, four activities of five minutes each, and a five-minute conclusion.

When planning the lesson, we thought it would be more effective to provide some sort of context to the coding and robotics lessons. This was done to provide the children with not only the context of what to do, but would excite, intrigue, and keep them engaged due to following a story line that is interesting. The lesson aimed to

address a few technological skills related to coding and robotics. Each activity in the lesson planned to focus on one or more 21st century thinking skill as well. The participating children were provided with an introduction to, and basic understanding of what coding and robotics entails. The technological knowledge was then extended in the second lesson.

The technological knowledge that was planned for this activity is listed below:

- Basic understanding of what the robot can do and how to manipulate it (specifically the Coding Critter).
- Direction (forward, backwards, left, right) mainly forward, right, and left.
- With more independence, the learners would be given the opportunity to understand the use of a grid where one block equates one step/action.
- How to construct their own action sequences.

The introduction of the second lesson then introduced the theme of pirates. The researcher and the participating teacher wore something appropriate to the pirate theme. This was aimed to get the learners questioning and guessing what they would be doing in the lesson. The introduction then focused on the children's understanding of their right and left sides. This terminology was enforced throughout the rest of the lesson. The children were encouraged to line up along a taped line on the floor, where after they were asked to raise their arms or legs on their right and left side. This movement was planned to start slow and then increase to a faster rate. Each child was then to be given a plastic 'pirate ring', which was a plastic child's dress-up toy ring, that is, a skull and cross bone. The ring had to be placed on their right hand to help the learners know and remember their right from their left side.

The lesson was then divided into four activities, which each aimed to address different 21st century skills. The children were divided into pairs and one group of three when moving between the different activities. The learners were required to spend five minutes completing each activity. The four activities are explained in detail below:

1. A grid consisting of 5x5 blocks was taped to the floor. There were boxes (treasure chests) placed in different blocks; each chest had a number written

on it. Inside each chest, there were a series of surprises or scares. Some of the treasure chests had ‘treasure’ in them, for example, plastic rubies or plastic gold coins. However, some chests had ‘scares’ inside instead, for example, they had plastic skeleton toys or plastic snakes inside. The children had to work in pairs. One child played the role of the pirate and had to move across the 5x5 grid while the other child was the treasure map reader. The map reader then had to select a coin that had a number on it and would use the map to guide the pirate (their teammate) to the correct treasure chest. The children took turns being the pirate and the map reader. Figure 4.9 below illustrates how the treasure map looked:

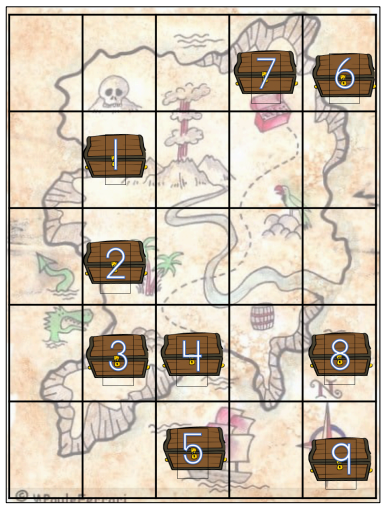


Figure 4-9: Lesson 2 - the treasure map used to guide the learners

Figure 4.10 below presents the layout of the grid and the role of the pirate and map reader as the activity was taking place.

Figure 4-10: An image showing the roles of the pirate and map reader in Lesson 2

This activity aimed to develop the 21st century skills of critical thinking and communication.

2. The second activity that was planned focuses on the learners' creativity. The learners were given a box of Lego and posed the task of building their own mini pirate ship. The learners were encouraged to be creative and build a pirate ship in whatever way they wanted. The researcher asked open-ended questions regarding the creation they had made and what made it a pirate ship: *What makes the construction they built look like a pirate ship? Where is their pirate ship going? What is the pirate ship going to do? Who is the captain of their special pirate ship?*

Figure 4-11: Learners engaging with Lego in Lesson 2

This activity aimed to develop the 21st century skill of creativity.

3. In the third activity, the learners worked with the Coding Critters. The learners were given the following problem to solve by trial and error: *Can you code your critter to move to the pirate cave and back?"* The children, working in pairs, had to take turns and try to get the Coding Critter to move to the pirate cave and back. This activity focused on the learners' ability to think critically and achieve through trial and error. The children all had a starting point and had to keep retuning to that starting point until they got it right. There was no correct way of getting to the pirate cave, thus the children could choose their own course, whether it was a forwards and backwards course, or the Coding Critter had to move forward and turn around.

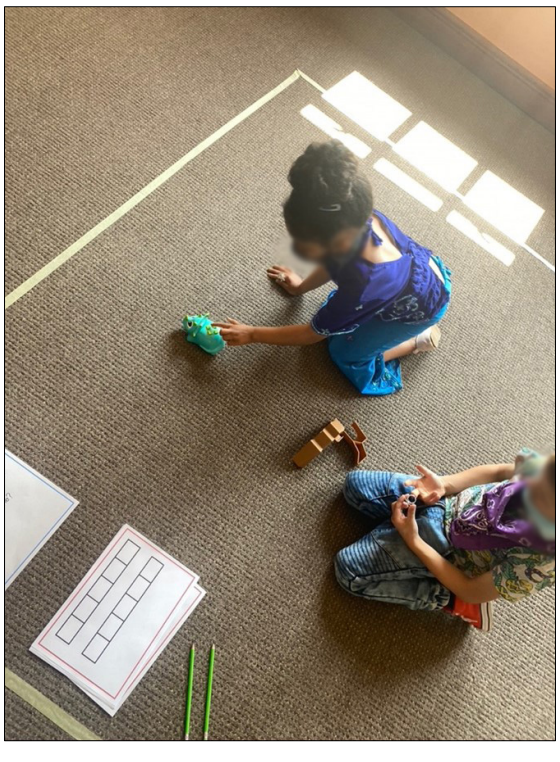


Figure 4-12: Learners manipulating the Coding Critters with sequence strips in Lesson 2

This activity aimed to develop the following 21st century skills: communication, critical thinking and collaboration.

4. The fourth activity involved both a grid and a Coding Critter. The children received a basic grid on top of a pirate map. The children then worked in pairs where one of them would choose the block where the treasure should be placed using the Coding Critter and linear blocks. The children then had to draw a sequence with arrows to retrieve the treasure. One child had to draw the arrows while the other child was in charge of coding the robot. The children took turns, thus alternating roles.

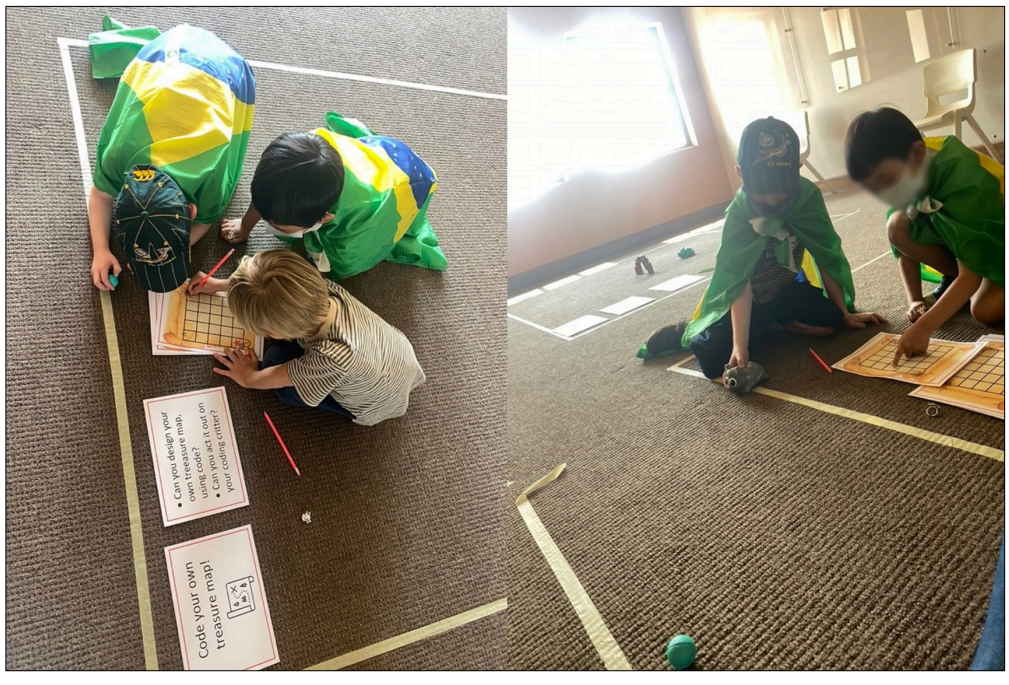


Figure 4-13: Learners manipulating a Coding Critter with a grid in Lesson 2

This activity aimed to develop the following 21st century skills: communication and critical thinking.

The conclusion chosen for this lesson was planned to last five minutes. The learners each received a grid and a pencil. The learners then had to use arrows to create a path to retrieve the treasure (diamond) and not get the dangerous skull or grey block.

4.1.2.2 Act and observation

Table 4.4 depicts a summary of the 21st century skills development as observed during the second lesson. The observation schedule for this particular lesson can be found in Appendix E. The first column in the Table 4.4 states the 21st century skill being addressed. The second column is the activity section, which indicates 21st century skill was planned for which activity in the lesson. The second last column displays how the application of the skills were planned, and the final column provides a brief discussion.

Table 4.4: SRQ 3- Lesson 2 - 21st century skills development results

Lesson 2: 21st century skills development						
21st Century Skill	**Activity**				**How skill was planned**	**Discussion**
	1	**2**	**3**	**4**		
Communication					Learners **guided their partner.**	In the first activity, the learners were encouraged to communicate with one another as they had to guide a partner who was blindfolded into the correct direction in order to collect the correct 'treasure box'.
	×		×	×	**Working in pairs through the process of trial and error**.	The skill of communication was also developed in the third activity as the learners had to work in pairs to try to get the Coding Critter to move to the pirate cave and back. This encouraged the learners to talk to another and correct themselves through trial and error. They had to express themselves appropriately in order to be successful in this activity.
					Activities that encourage effective **communication in written and verbal form.**	The fourth activity also focused on developing the learners' communication skills as they were encouraged to work together to get the Coding Critter to retrieve the 'treasure'. While one learner had to express themselves in written

Lesson 2: 21st century skills development						
21st Century Skill	Activity				How skill was planned	Discussion
	1	2	3	4		
						form (by drawing the arrows on the grid), the other learner had to communicate through their actions as they had to use the Coding Critter to follow what was presented by the arrows. This encouraged the learners to communicate in written and verbal form.
Collaboration		×			**Solving problems and evaluating solutions as a team.**	The third activity focused on developing the learners' collaboration as they went through the process of trial and error to get the Coding Critter to move to the pirate cave and back. This made the children think of a specific sequence and then when it did not work, they had to start again but adapt the sequence that was previously used to be more accurate. The learners had to work together effectively in order for the Coding Critter to successfully get to the pirate cave and back.
Critical Thinking					Learner has the opportunity **to think of their own routes that are simple for another person to follow.**	The first activity aimed to support the development of critical thinking as the learner who was given the role of reading the map had to construct a route to get the treasure without leading their partner to other treasures. The map reader had to find the quickest and easiest route for the partner to follow.
	×		×	×	**Solving activities** through the method of **trial and error**.	The third activity also focused on the development of critical thinking as the learners had to think through the method of trial and error. They had to constantly re-evaluate and alter the sequence they had planned in order for the Coding Critter to reach the pirate cave.
					Constructing sequences for someone to follow on a grid.	The fourth activity helped the learners develop their critical thinking as they focused on the best route to get the Coding Critter to retrieve the treasure, as well as use a pirate map, as a basic grid.
Creativity		×			**Building and constructing** from their **own design.**	The second activity focused mainly on developing the 21st century skill of creativity. The

Lesson 2: 21st century skills development						
21st Century Skill	Activity				How skill was planned	Discussion
	1	2	3	4		
						activity encouraged the learners to be creative when designing their own pirate ships out of Lego. The learners had to think ahead to what would realistically look like a boat.

The four 21st century skills focused on in this study were observed throughout this lesson. The skill of communication was planned in three of the four activities, critical thinking in three of the activities, and collaboration and creativity in one activity each. The main observation in this lesson was the learners' engagement with one another once dividing them into pairs or groups. This encouraged the learners to communicate with one another and to work together to solve problems. Table 4.5 summarises the coding and robotics principles that were developed during Lesson 2.

Table 4.5: SRQ 2- Lesson 2 - coding and robotic development results

Coding and robotics development in activities
• **Basic understanding of what the robot (the Coding Critter) can do and how to manipulate it.** This technological skill was planned to be developed in the third and fourth activities as the learners used the Coding Critter in different manners. Learners needed to learn to follow a set of actions (a sequence), and use trial and error to attain the goal of getting the Coding Critter to an object and back.
• The children had a greater **understanding of direction**. The children focused on learning the terminology and meaning of the directions: forward, backwards, left, and right, especially focusing on forwards, left and right. This was supported specifically in the first activity, however, due to the learners working in pairs, it continued to develop in activities three and four.
• With more independence, the learners gained a greater understanding of **the use of a grid**. The learners came to understand that one block is equivalent to one step or action. This skill was developed in the conclusion.
• The construction of their own **sequences** in activities three and four developed the learners' understanding of how to correctly construct their own sequence and the different factors to consider.

During this lesson, the learners' basic understanding of what a robot can do was revised and extended. They were also introduced to the use of a grid and a sequence. The learners began to explore these aspects with more independence.

4.1.2.3 Reflect

The reflection on the results for Cycle 2 are provided in Table 4.6.

Table 4.6: SRQ 1- Lesson 2 - reflections

Key aspects addressed throughout the study	**Lesson 2**	**End of AR Cycle 2 reflections** • For this activity, a pirate **theme** was the foundation for the lesson. The use of a theme allowed the learners to immerse themselves in the task at hand, while allowing them to have fun and use their imagination- the children loved using their imagination to complete a task. It gave context to what they were required to do in a fun way. • The activities had a **story with relevance**. In this lesson, there were stories that occurred - this provided the learners with a background and a plan for each activity, which was fun and held their interest. Each activity had its own story line that allowed the learners to get involved and start drawing their own conclusions. • Carry out **fewer activities** while allowing the learners to complete the activities in a calm manner - the learners rushed between each activity as they were excited to engage in each activity. This gave the whole lesson a hurried experience. Instead, the lesson should contain fewer activities, or the duration of the activities should take a shorter period of time. This will allow the children to engage in each activity without feeling rushed, overwhelmed, or that they may possibly be left out. • After the last lesson, we incorporated the use of a **timer** - this helped with time management as the children knew they could not move on from an activity until the time was up. This also meant that they could not stay too long at their favourite activity. Using the timer gave the children authority over their own completion of the activities. • The use of other **concrete apparatus** encouraged the learners to actively engage with one another and ask questions. In this lesson, this comprised the use of more concrete apparatus, such as the treasure and the pirate maps. This allowed the learners to engage in each activity, to discuss and ask questions. This is exactly what we wanted to occur as it encourages the development of communication skills between the children. • Not all activities had the same **level of difficulty** - this added to the hurried experience that occurred as some learners had completed an activity before others and began to play, thus the other learners who were still completing the activity felt rushed. In future, this should be better managed so that the lesson timing is evenly split between similar activities.

The most significant reflections at the end of Cycle 2 included the use of a theme or a story, which creates relevance; the use of a timer to manage time; and the incorporation of more concrete apparatus.

4.1.3 Lesson 3

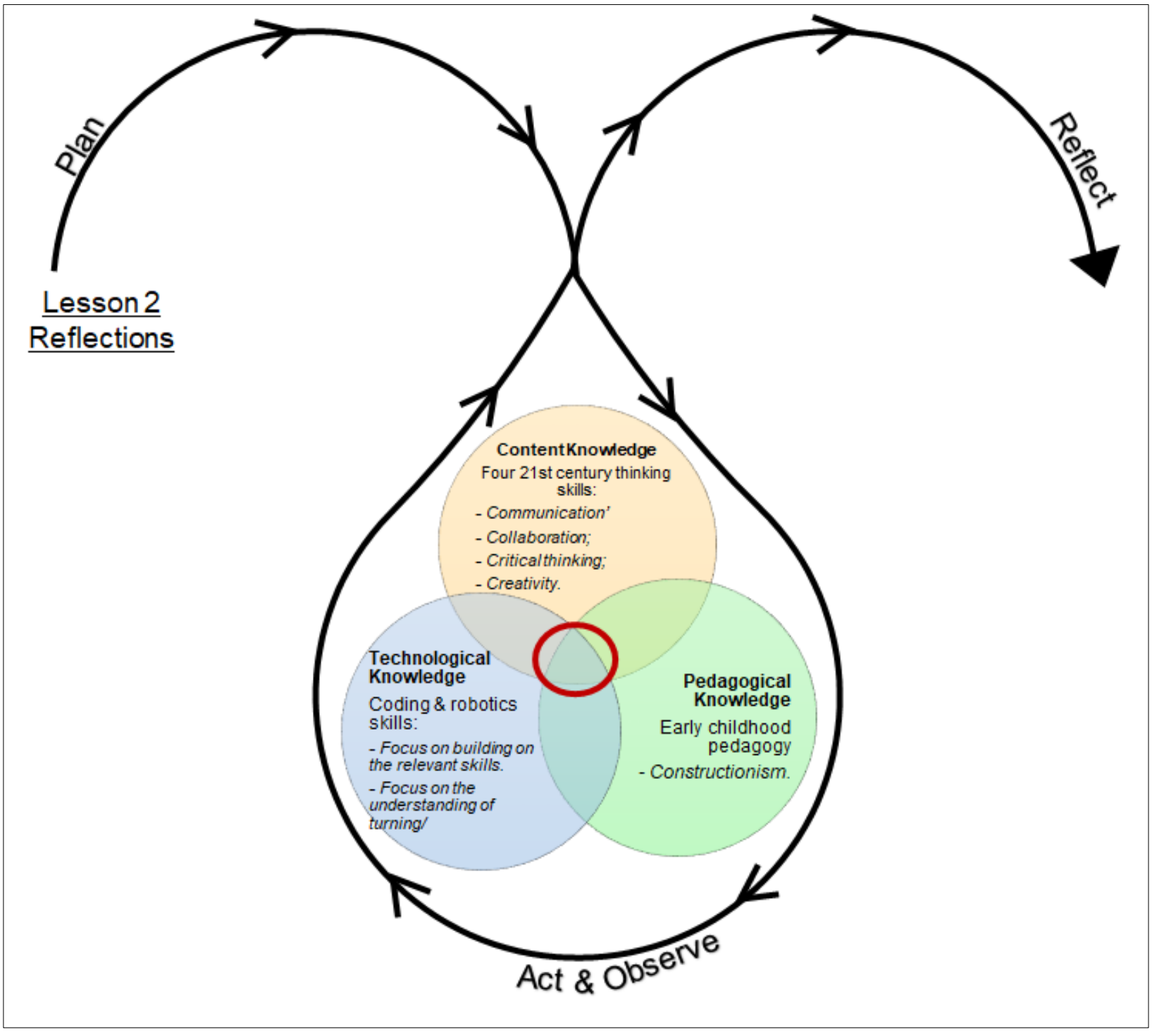


Figure 4-14: Lesson 3 Action Research process and TPACK

Figure 4.14 provides a summarised illustration of the current lesson cycle.

4.1.3.1 Plan

The third lesson was planned to have a western theme. The children were encouraged to take on the roles of cowboys and cowgirls. The lesson aimed to continue addressing the technological skills that were focused on in the previous lessons. Each activity in the lesson planned to focus on one or more 21st century thinking skill. Their technological knowledge continued to develop in comparison to the previous lessons.

The technological knowledge that was planned for this activity was as follows:

- Develop vocabulary regarding the action of turning.

- Develop the ability to follow a sequence.
- Develop the skill to think and plan ahead and then relate this thinking to a sequence.
- Develop the ability to construct their own coding sequence.
- Develop the ability to manipulate the Coding Critter to turn around.
- Develop the ability to discover a route along a grid using arrows.

The introduction of the activity introduced the children to the theme of this lesson, which was the Wild West. The introduction focused on the children's memory of the specific vocabulary when explaining to their friends where to go. This terminology was enforced throughout the rest of the lesson. The children were encouraged to line up along a taped line on the floor. They then had to follow the instructions given by the researcher and participating teacher. One at a time, the children had to take turns instructing one another using the basic terminology. Once they had successfully instructed their friends back to the taped line, they would receive a sheriff badge. As depicted in Figure 4.15 below, the sheriff badge has different images on each point of the badge. The different images represent the different activities that the children had to complete. Each activity was explained beforehand. The children were encouraged to listen to the timer when changing stations, and to cross off each activity once completed.

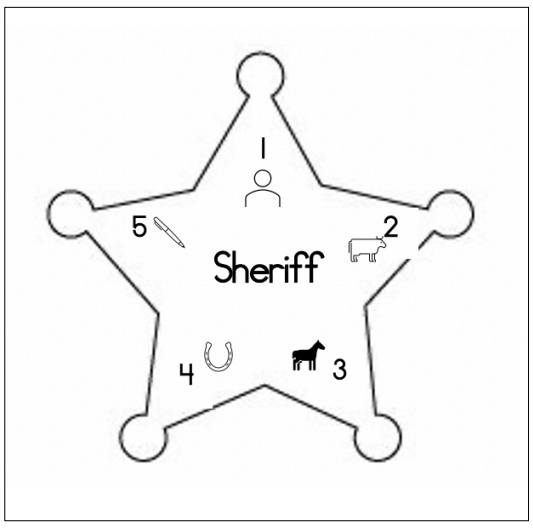


Figure 4-15: The sheriff badge used to manage the learners' completed activities

The lesson was then divided into four activities. These four activities aimed to address different 21st century skills. The children were divided into pairs and one group of three when moving between the different activities. The learners had to

spend five minutes completing each activity. The children then needed to wait for the timer before moving onto the next activity. The four activities are explained in detail below:

1. The first activity had a 4x4 grid that was placed on the floor with ‘Most Wanted’ picture cards. All of the cards were placed upside down. There was one outlaw in the pack of cards, and the aim of this activity was to find the outlaw card. The other cards were cartoon characters or pictures of the researcher and participating teacher. If a child picked up the outlaw card, they would get a point. If they picked up a card that was not the outlaw, they did not get a point. The learners first received a sequence of cards, which led them to finding the outlaw. Figure 4.16 below shows the sequence that the learners received.

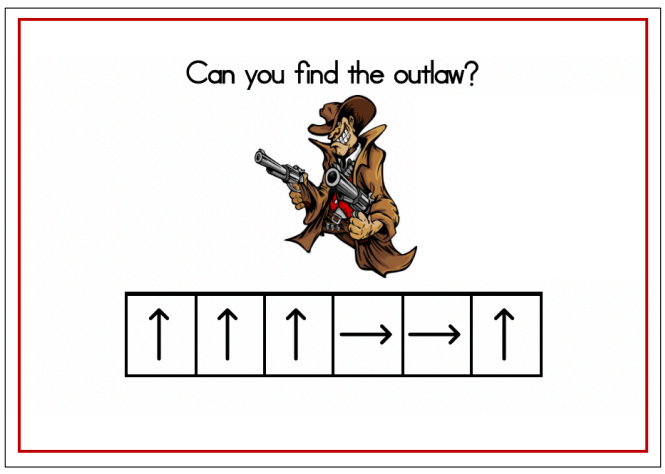


Figure 4-16: Sequence card the learners followed

Once the outlaw was found, they took turns to hide the outlaw in a new position. The child who hid the outlaw then drew arrows leading to the new position while the other child closed their eyes. Once the arrows were completed, the learner who closed their eyes used the arrows that the first children drew to find the outlaw. The children took turns placing the outlaw and finding him. At the end, the child with the most points won. Figure 4.17 below displays the researcher observing the children during the activity, and asking the children to explain what they were doing during the activity.

Figure 4-17: The learners engaging in the first activity of Lesson 3

This activity aimed to develop the following 21st century skills: communication skills, critical thinking skills and creative skills.

2. The second activity focused on the learners' ability to get their Coding Critter to turn. The aim of this activity was to get the Coding Critter to go around the 'cattle'. The 'cattle' used in this activity consisted of images of cows scattered around the floor. The children had to program the Coding Critter to go around all of the cow cards. The children completed this activity through trial and error. Figure 4.18 depicts the layout of how the activity was set up.

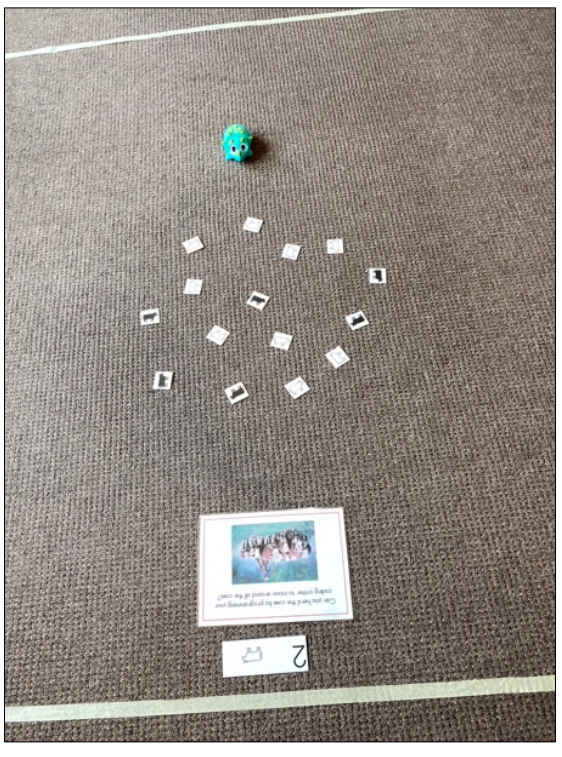


Figure 4-18: Activity 2 of Lesson - showing the layout of the activity

This activity aimed to develop the following 21st century skills: collaboration and critical thinking.

3. In this activity, the children were required to feed the horses. The children were given different strips that showed the order of the different horses that needed to be fed. The strip contained pictures of the actual toy horses that were used. Figure 4.19 shows the sequence strips that were given to the children.

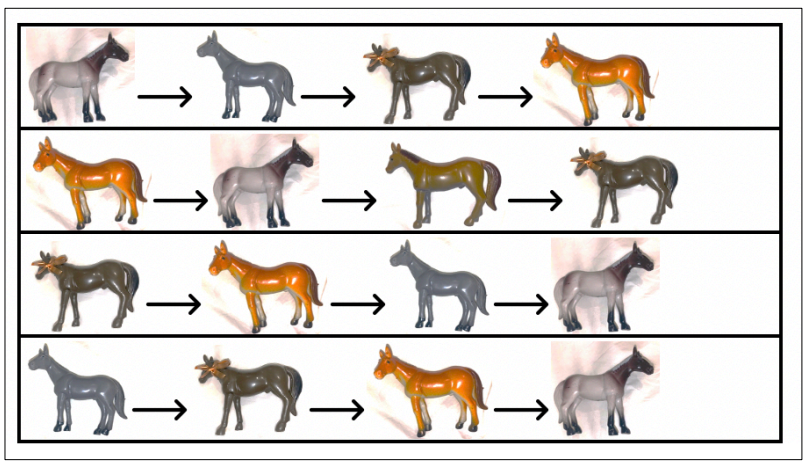


Figure 4-19: Sequence strips given to the children

The children had to use the Coding Critter to move between the different horses to tap (feed) the horse. The children, working in pairs, took turns and tried get the Coding Critter to move to the different horses and in the correct order without knocking over the incorrect horse. Figure 4.20 shows a child programming the Coding Critter to move to the different horses.

Figure 4-20: An image of a child completing Activity 2 of Lesson 3

This activity aimed to develop the following 21st century skills: collaboration and critical thinking.

4. In the fourth activity, the researcher posed the following question, “Can you build a horse out of Lego?” The children were encouraged to make their very own creations. The researcher did, however, give the learners a hint. The researcher asked open-ended questions regarding the creation they had made and why it looked like a horse. Figure 4.21 depicts the hint that the researcher gave to the children.

Figure 4-21: The hint given to the children in Activity 4 of Lesson 3

Figure 4.21 shows a creation that one of the children made after following the hint and instructions given to them.

Figure 4-22: Child completing Activity 4 of Lesson 3

This activity aimed to develop the 21st century skill of creativity.

The conclusion was chosen to continue to develop the learners' confidence in using a grid. The children were given a western themed grid. Using arrows, the children had to create a path to get the horse to the stable without walking into a cactus. There were multiple ways in which the children could complete this task. The children were then encouraged to compare with each other regarding another way in which they could move the horse to the stable. Figure 4.23 presents the grid that the children completed.

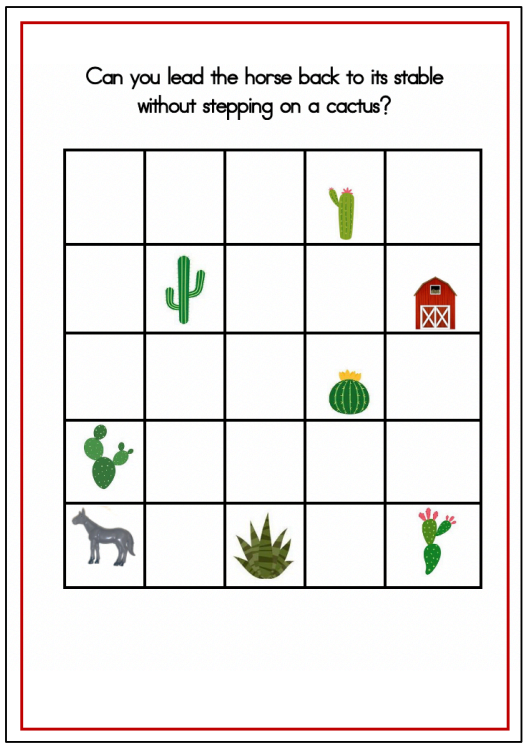


Figure 4-23: Grid used in the conclusion of Lesson 3

Figure 4.24 below shows images of the children completing the grid and discussing their chosen paths with one another.

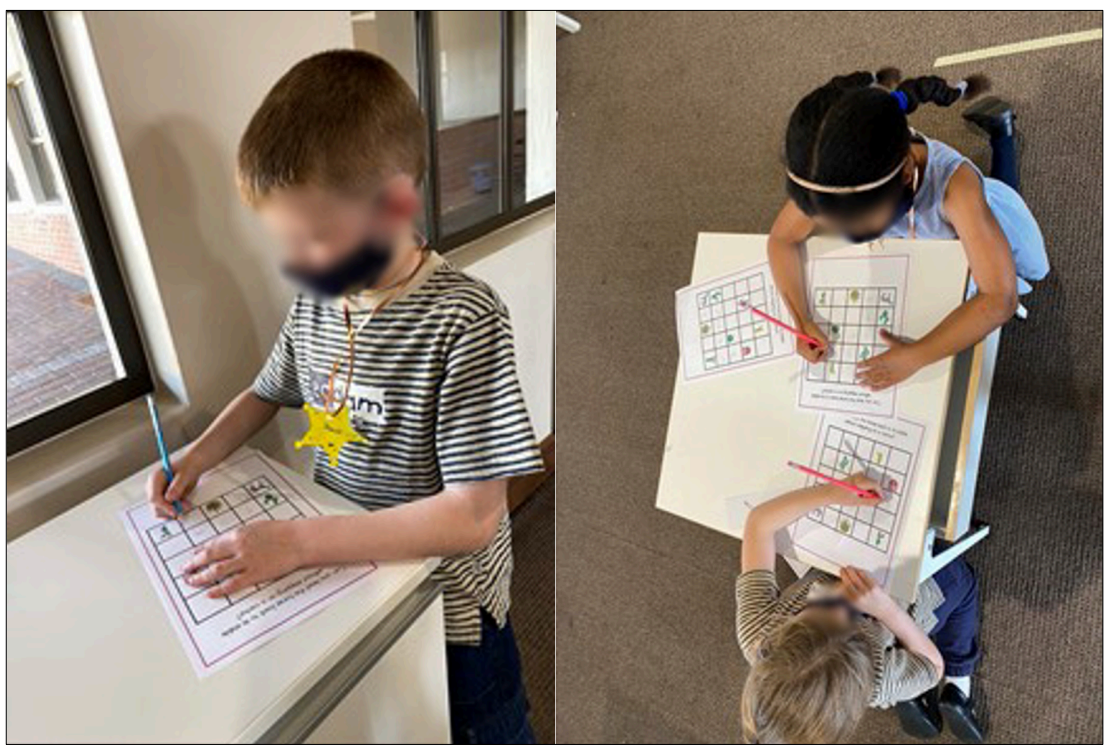


Figure 4-24: Children completing the conclusion grid for Lesson 3

4.1.3.2 Act and observation

Table 4.7 depicts a summary of the 21st century skills development as observed during the third lesson. The observation schedule for this particular lesson can be found in Appendix E. The first column in Table 4.7 states the 21st century skill being addressed. The second column is the activity section, which indicates the 21st century skill planned for each activity in the lesson. The second last column displays how the application of the skills was planned, and the final column provides a brief discussion.

Table 4.7: SRQ 3- Lesson 3 - 21st century skills development results

Lesson 3: 21st century skills development						
21st Century Skill	**Activity**				**How skill was planned**	**Discussion**
	1	**2**	**3**	**4**		
Communication					Using **correct terminology** while guiding a partner.	In the lesson as a whole, the children were encouraged to develop their ability to communicate with one another and guide one another with the correct terminology. The terminology specifically related to the action of turning. In the first activity, the learners developed the skill of communication by guiding their friend to find the outlaw card. One child had to place the card in a specific area and then guide a friend to the location of the card. The child had to use the correct terminology, as well as guide their partner correctly.
	×					
					Discussions around **comparing own findings.**	In the conclusion, the learners developed their skill of communication as they had to verbalise the route/sequence they found on the grid, as well as discussing it with the other children. The children were encouraged to discuss and compare unique and different routes.

Lesson 3: 21st century skills development						
21st Century Skill	**Activity**				**How skill was planned**	**Discussion**
	1	**2**	**3**	**4**		
Collaboration					**Solving problems in groups.**	In the second activity, the learners were encouraged to work with their partner through trial and error to get the Coding Critter to move around the cow cards. The activity focused on getting the learners to think of new ways, and to work together.
		×	×		The learners **rely on one another to help and guide with reflections and suggestions** to successfully complete the activity.	The third activity focused on getting the children to work together to get the Coding Critter to move between the different horses and in the correct order. This activity required the children to work together, discussing and collaborating in order to be successful.
Critical Thinking					Learners are encouraged to think for themselves and **take authority** over the activities and their learning.	The lesson as a whole focus on the learner's ability to think critically and the children are encouraged to move between the different activities and think for themselves in each activity.
	×	×	×		**Effectively evaluate different scenarios** that can occur.	The first activity encouraged the children to think critically as they had to construct their own sequences. They also had to guide their partner to discover their outlaw. By doing this, the children had to think critically as they evaluated the different scenarios, that could occur.
					Using **trial and error to effectively manipulate** a Coding Critter.	The second and third activity allowed the children to think critically as they used trial and error to solve the problem. The children had to think of ways to manipulate the Coding Critter to move in order to achieve the desired outcome, whether it was to feed the horses or move around the cows.

Lesson 3: 21st century skills development						
21st Century Skill	**Activity**				**How skill was planned**	**Discussion**
	1	**2**	**3**	**4**		
Creativity	✕			✕	**Working individually** to create their own sequence and story. **Pose a task**, with **little guidance** and learner is encouraged to construct and build from imagination.	The first activity encouraged the children to be creative when constructing their own sequences and hiding the outlaw to which their friend had to be guided. The fourth activity focused on developing the learners' skill of creativity as they were tasked to build their very own horse out of Lego.

This lesson observed the four 21st century skills throughout. The skill of communication was consciously planned once in the first activity, collaboration and creativity were planned and integrated into two activities, and the skill of critical thinking was planned for in three different activities. The main observations that were discovered in the lesson were the encouragement of learners using the correct terminology when guiding a friend, the children's ability to work together in a group to solve problems, and their ability to effectively use trial and error.

Table 4.8 summarises the development of coding and robotics principles developed during Lesson 3.

Table 4.8: SRQ 2- Lesson 3 - Coding and robotic development results

Coding and robotics development in activities
• The children developed the **vocabulary** regarding the action of turning. This skill was developed in the introduction, and the second and third activity. The children were encouraged to use the correct terminology when guiding their friend, but specifically in this lesson, the activities focused on getting the learners to explain to their friends how to turn.
• The children developed the ability to **follow a sequence** in the first activity and the conclusion. The children developed their own sequence to solve a problem or to guide their partner to complete the task.
• The children developed the skill to think and **plan ahead** and then relate this thinking to a **sequence** in the first, second, third, and fourth activity. This ability linked to the learners' development of critical thinking in this particular lesson. The learners were required to plan and consider all factors while creating a sequence.
• The ability to **construct their own coding sequence** was developed in the first activity and the conclusion. The learners had to be creative in their own thinking and the creation of their sequences, as well as having the correct outcome.
• The ability to **manipulate the Coding Critter to turn around** - the children had to not only be able to use the correct terminology, but also be able to manipulate the Coding Critter to turn around. This was developed in the second and third activities. The children were posed with tasks in these activities that focused on the learners turning the Coding Critter.
• The ability to **discover a route in a grid using arrows** meant that the learners had to be creative in their construction of sequences in a grid, as well as move around obstacles in the grid. This was developed in the conclusion of the lesson.

In this particular lesson, the key aspects observed were the use of appropriate vocabulary, the ability to create and follow a sequence, an increase in confidence to manipulate the Coding Critter to turn, as well as creating unique routes on a grid.

4.1.3.3 Reflect

The reflection results for Cycle 3 are presented in Table 4.9.

Table 4.9: SRQ 1- Lesson 3 - reflections

Key aspects addressed throughout the study	**Lesson 3**	**End of AR Cycle 3 reflections** • The implementation of the western cowboys and cowgirls' **theme** was successful. The implementation of the themes allowed the children to develop 21st century skills as they communicated regarding the story of the cowboys/cowgirls and the different scenarios that occurred; and they collaborated to solve a relevant problem. They were creative regarding the theme and building something relevant to the theme, for example, the horse out of Lego. The children were encouraged to think critically of different scenarios in the correct context. This was mainly seen in Activity 1. • The **timer** was effective as it allowed the children to complete all activities, however, they did not get time to play. Therefore, in future, more time is needed, and the activities need to be equal in the time spent. • The sheriff star was a useful resource that encouraged the children to **check off** the different **activities** that they had completed themselves. It was effective for some of the children, however, the children wanted to focus more on the activity instead of checking the activities off. • During the conclusion, the children interacted in a **larger group instead of in pairs**. This got the children discussing interesting routes/scenarios and correcting each other without the intervention of the researcher/teacher. This allowed for the children to speak more and explain differently to different children, and make it relatable to more than one other learner. • To ensure that each of the four 21st century skills were met, there was a **designated activity** that focused mainly on that skill. This allowed for all of the skills to be developed. Therefore, we found it to be beneficial that each activity focused on one or more 21st century skill.

Cycle 3 consisted of significant reflections. These reflections include: the continuation of a theme; the importance of time management, whether by use of a timer, or additional resources to check completed activities; the children working together in larger groups; and assigning different 21st century skills to particular activities.

4.1.4 Lesson 4

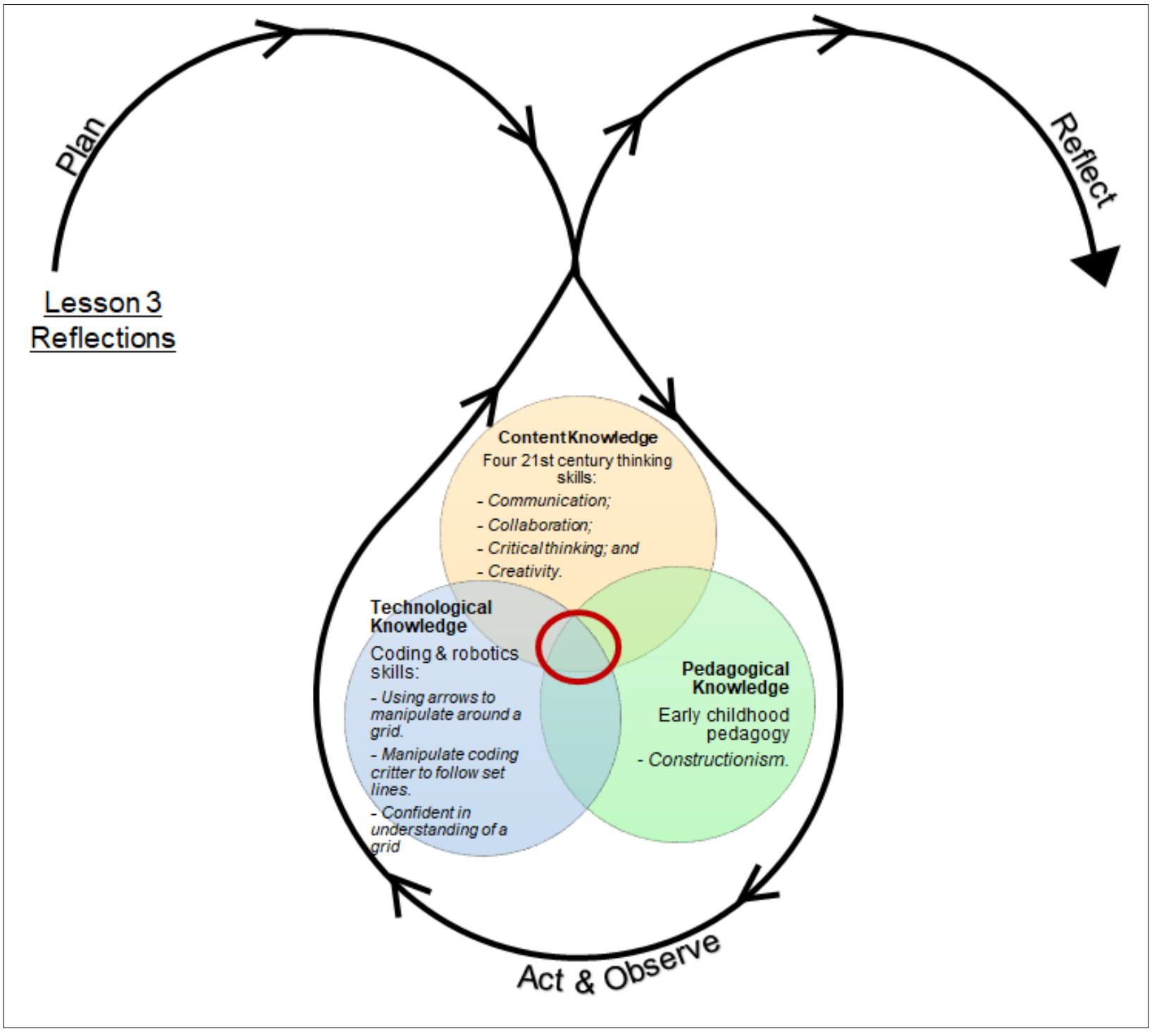


Figure 4-25: Lesson 4 Action Research process and TPACK

Figure 4.25 provides a summarised illustration of the current lesson cycle.

4.1.4.1 Plan

The fourth lesson was planned to have a detective. Throughout the lesson the children had to solve clues regarding a jewel thief named Peter the Cheater. The lesson aimed to encourage the children to think ahead, analyse, and plan, just like a detective. The content knowledge in this lesson continued to focus on the development of the children's 21st century thinking skills.

The technological knowledge that was planned for this activity is listed below:

- The children should gain confidence in their understanding of a grid.

- The children should be able to use arrows to manipulate the Coding Critter around a grid.
- The children needed to be able to manipulate the Coding Critter to follow a pre-planned course (lines).
- The children should gain the ability to decode (in this lesson the picture icons) to combine and construct their own meaning of a story.

The introduction of the lesson got the learners motivated for the lesson ahead. The introduction required the children to communicate and collaborate with one another while trying to solve a mystery with only some icon pictures as clues. The children were given a piece of paper with a sequence of pictures, as seen in Figure 4.26 below.

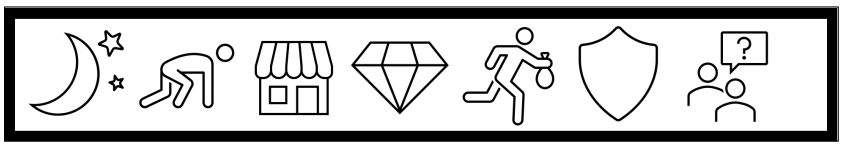


Figure 4-26: The picture sequence strip given to the children in Lesson 4

The children were encouraged to work in pairs to decode the sequence of pictures regarding what they thought happened the night of the robbery, this is shown in Figure 4.27. The researcher then told the learners the correct order of events.

Figure 4-27: An image of the learners solving the picture sequence strip in Lesson 4

The lesson was then divided into three activities, which were supposed to be five minutes long each. The activities aimed to address different 21st century skills. For the activities, the children were divided into groups of three. The three activities are explained in detail below:

1. The first activity focused on the children's ability to manipulate the Coding Critter to move across a pre-planned course along the taped lines. The children had to code the Coding Critter to try to 'catch the jewel thief' by coding the Coding Critter to correctly follow the path taken by the thief. The children completed this activity through trial and error. Figure 4.28 below shows the learners working together to code the Coding Critter.

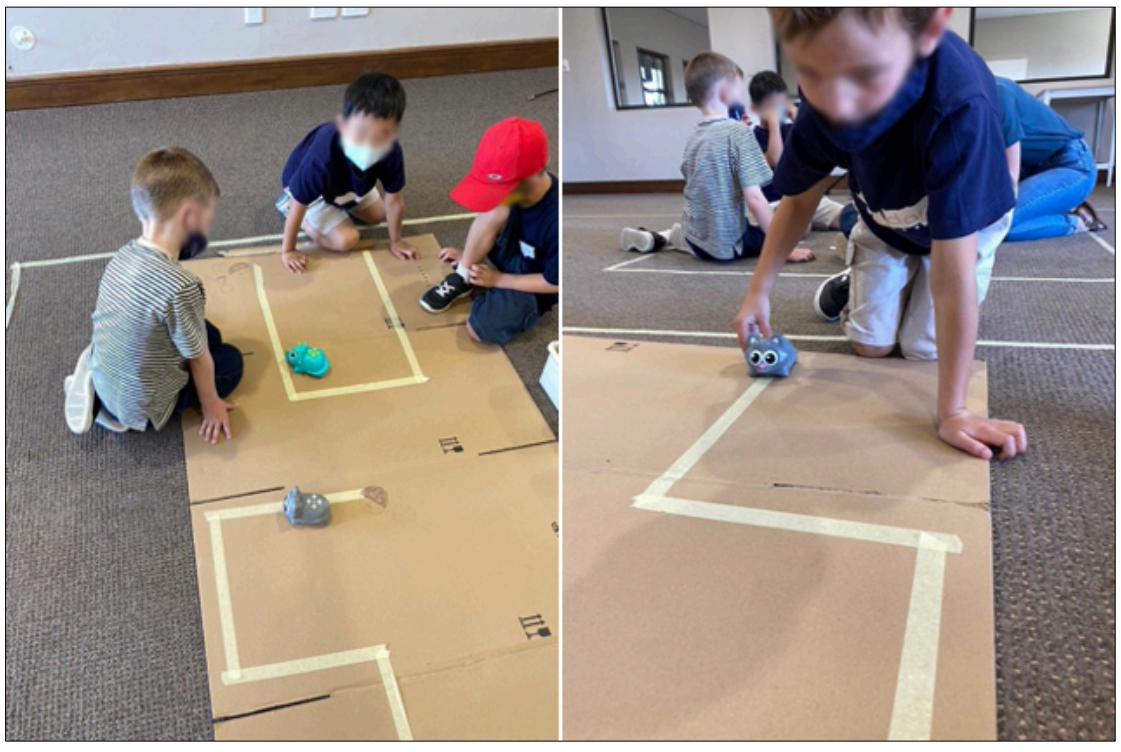


Figure 4-28: Images showing the children manipulating the Coding Critters in Activity 1 of Lesson 4

This activity aimed to develop the 21st century skills of collaboration and critical thinking.

2. The second activity encouraged the children to engage in problem solving. Continuing with the storyline of Peter the Cheater and the missing jewel, this activity consisted of a 4x4 grid that was made up of picture cards. The cards were placed upside down. There was one card that had a jewel on it and if the children picked up the jewel card, they got a point. If they picked up a card that did not have a jewel, they did not get a point. The children had to use a sequence strip with arrows to find the bag with the jewel. The

researcher engaged with the learners as they discussed their process of discovering the jewel card by following a sequence, as seen in Figure 4.29.

Figure 4-29: An image of the children engaging with the card grid in Activity 2 of Lesson 4

This activity aimed to develop the 21st century skills of collaboration and communication.

3. The fourth activity encouraged the children to use their imagination to build a key out of Lego. Linking back to the story, the children were creating a key that would be used to lock Peter the Cheater away. They were encouraged to be creative and to think of their own way to build a key. Figure 4.30 shows a learner who built a key out of Lego explaining to the researcher the different parts and the reason for the different colours.

Figure 4-30: An image of a completed Lego Key for Activity 3 of Lesson 4

This activity aimed to develop the 21st century skill of creativity.

The conclusion involved all of the children working individually. The conclusion continued with a story-like introduction. Because the children could not read yet, the researcher had to read at the start. The researcher read the sequence of events that happened the night that Peter the Cheater stole the jewel. The children had to code on a grid the series of events that linked to the story and in which cabin they believed Peter the Cheater was hiding. The children used arrows to create a path on the grid. The children had to communicate and collaborate with one another. The children explained the paths that they created on the grid to their classmates and the researcher, which is depicted in Figure 4.31.

Figure 4-31: Children completing the individual grid concluding Lesson 4

4.1.4.2 Act and observation

Table 4.10 provides a summary of the 21st century skills development as observed during the fourth lesson. The observation schedule for this particular lesson can be found in Appendix E. The first column in Table 4.10 below states the 21st century skill being addressed. The second column is the activity section indicating the 21st century skill planned for each activity in the lesson. The second last column displays how the application of the skills were planned, and the final column provides a brief discussion.

Table 4.10: SRQ 3- Lesson 4 - 21st century skills development results

Lesson 4: 21st century skills Development					
21st Century Skill	**How skill was planned**			**Discussion**	
	1	**2**	**3**		
Communication				Learners **take leadership** of the activities and their own learning.	Throughout the fourth lesson, the children were encouraged to communicate and work with one another. The children had to express what they wanted to do and how they wanted to do it.
				Learners **verbalise their own thinking**.	In the introduction, the children worked in pairs to solve a sequence card that only had picture icons as clues for how the robbery occurred. The children had to work together to decode the pictures and then they had to verbalise how they decoded the pictures to the researcher and participating teacher, who then listened and corrected when needed.
		×		**Working together to solve a problem.**	In the second activity, the children communicated with one another as they tried to solve where the jewel was hiding by reading the arrows on the sequence strip. The children had to communicate with one another in order to work effectively together.
				Learners must **justify and compare** their own thinking to their fellow classmates.	The children also focused on developing their communication skills in the conclusion as they listened to the researcher explain the sequence of events which led to where Peter the Cheater was hiding. Once the children had drawn their own arrows on the grid, they had to communicate with their classmates and explain where they thought Peter the Cheater was

Lesson 4: 21st century skills Development					
21st Century Skill	**How skill was planned**				**Discussion**
	1	**2**	**3**		
					hiding and why they think he went that route.
Collaboration				Work together to **decode and create meaning.**	In the introduction, the children had to work together to decode the picture icons and present what they believed occurred the night of the robbery. The children needed to collaborate with one another in order to solve the mystery.
				Effectively communicating while **solving a problem through trial and error.**	In the first activity, the children needed to work together through trial and error to get the Coding Critter to move along the pre-planned lines that were taped on the floor. The children needed to correct and help one another to achieve this task.
		×	×	Helping one another to **achieve a common goal.**	In the second activity, the children were trying to find the hidden jewel in a 4x4 gird. The children had to read the arrows and guide one another to find the jewel. They got points each time they found the jewel correctly.
				Peer evaluating – each child evaluating their own work and comparing with another's to **construct a unified conclusion.**	In the conclusion, the children worked individually, and once they had designed their own routes with arrows on their grid, they collaborated with one another to remember the sequence that Peter the Cheater travelled. The children were encouraged to explain and evaluate others' work effectively.
Critical Thinking				**Decode images to create a story.**	In the introduction of the fourth lesson, the children were encouraged to think critically as they had to decode a series of picture icons in order to solve what happened the night of the robbery. The children needed to think critically and construct their own conclusions.
		×		Learners think critically while **discovering solutions through trial and error.**	In the first activity, the children were encouraged to think critically as they went through the process of trial and error in order to code the Coding Critter to correctly follow the pre-planned tape lines. The children were not given an example and needed to discover for themselves how to

Lesson 4: 21st century skills Development				
21st Century Skill	**How skill was planned**			**Discussion**
	1	**2**	**3**	
			Learners **construct their own sequence while considering all of the factors** involved.	manipulate the Coding Critter to follow the lines. In the conclusion of the lesson, the children needed to think critically to construct their own routes that Peter the Cheater travelled, as well as doing so in the correct order that the researcher told them in the story. The children needed to think critically of the route and in which cabin on the grid Peter the Cheater was hiding out in. There was no perfect or single route. The children needed to think critically and creatively when designing their routes, however, these needed to be in the correct sequence that was told in the story.
Creativity		×	**Construct and build from imagination.** **Use imagination while factoring in particular events in a story.**	The children were encouraged to be creative in the third activity as they designed and built their own keys. The children were posed with the task of building their own key to lock up Peter the Cheater. The children used Lego to build their own keys without assistance. In the conclusion of the story, the children were encouraged to be creative while being observant of the possible routes that Peter the Cheater could have taken considering the events that occurred.

The four 21st century skills focused on in this study were observed throughout this lesson. Each activity tried to address one of the 21st century skills involved in this study. Communication was consciously planned for once in the second activity, collaboration in the two different activities, critical thinking was planned for in one of the activities, and creativity was planned for in the last activity presented. The main observations in this lesson were the importance of creating opportunities for the learners to verbalise their thinking, as well as working together to decode and create something.

Table 4.11 summarises the development of the coding and robotics principles developed during Lesson 1.

Table 4.11: SRQ 2- Lesson 4 - coding and robotics development results

Coding and robotics development in activities
• The children's confidence in their understanding of a **grid** was developed in the second activity as they tried to find the hidden jewel in a 4x4 grid. The children read arrows on a sequence strip to find the hidden jewel that was presented in the grid. The children also got a better understanding of grids in the conclusion when they worked individually to design their own route that they believed Peter the Cheater had taken based on the clues the researcher gave them. The children then compared their grids with those of their classmates and evaluated one another's grids.
• The children's ability to **use arrows to manipulate around a grid** was built further using a grid. This skill was developed in the second activity and the conclusion of the lesson as the children both read arrow sequences to complete the activity and discover the jewel, and drew their own arrows to complete the route they believed Peter the Cheater completed in the conclusion.
• The children's ability to **manipulate the Coding Critter to follow a pre-planned course (lines)** was developed in the first activity as they worked to solve the task of getting the Coding Critter to follow the pre-planned taped lines on the floor. This was completed using trial and error. The taped lines became more complex as the children completed each one. This encouraged the children to start using more buttons on the Coding Critter and in different and longer sequences.

During the fourth lesson, the aspects observed concerned the use of arrows to manipulate around a grid, basic robot care and actions, as well as the manipulation of a Coding Critter on a pre-planned course.

4.1.4.3 Reflect

The reflection results for Cycle 4 are provided in Table 4.12 below.

Table 4.12: SRQ 1- Lesson 4 - reflections

Key aspects addressed throughout the study	**Lesson 4**	**End of AR Cycle 4 reflections** • The implementation of a t**heme** continued to be successful. The children engaged well with the theme. The children could construct their own adventures. They engaged well with the theme, which also had a storyline. • The incorporation of the **storyline** proved to be incredibly effective. The children completed multiple activities that linked to the main story. This allowed the children to fully immerse themselves in the scenario and start thinking relative to what happened, thus building 21st century thinking skills. The children not only had an activity they had to complete, but a purpose to the task which aided in the continuation of the story. • The Lego activity in the lesson was **too easy** for the children to complete. The learners lost interest in the activity once completed. When presenting tasks regarding creativity, the suggestion is that the activity be a bit difficult for the learners. Be aware of the level of difficulty when planning activities. Rather create an activity that a teacher can guide or extend depending on the learner. • It was easy to manage the **time** with the learners as there were fewer activities for the children to complete. However, the key activity was completed with ease, and this left the children with extra time. It is important to ensure that the activities take the same amount of time to complete. • Although the children **had more time in the activities** because there were fewer activities, it was easier when more activities were presented as then the children were engaged for the full duration of the lesson. • The changing of the **groups** from pairs to groups of three allowed the children to communicate with someone else as well. This developed their communication and collaboration skills as the learners had to learn how to work together.

The most significant reflection at the end of Cycle 4 included the implementation of a theme or storyline in the lesson. The importance of being aware of the level of difficulty for the children, and allowing the more creative-led activities to be a bit more complex was highlighted. The management of time is an importance concept that was once again addressed in this lesson. The lesson also focused on changing groups and encouraging the children to work with other children as well.

4.1.5 Lesson 5

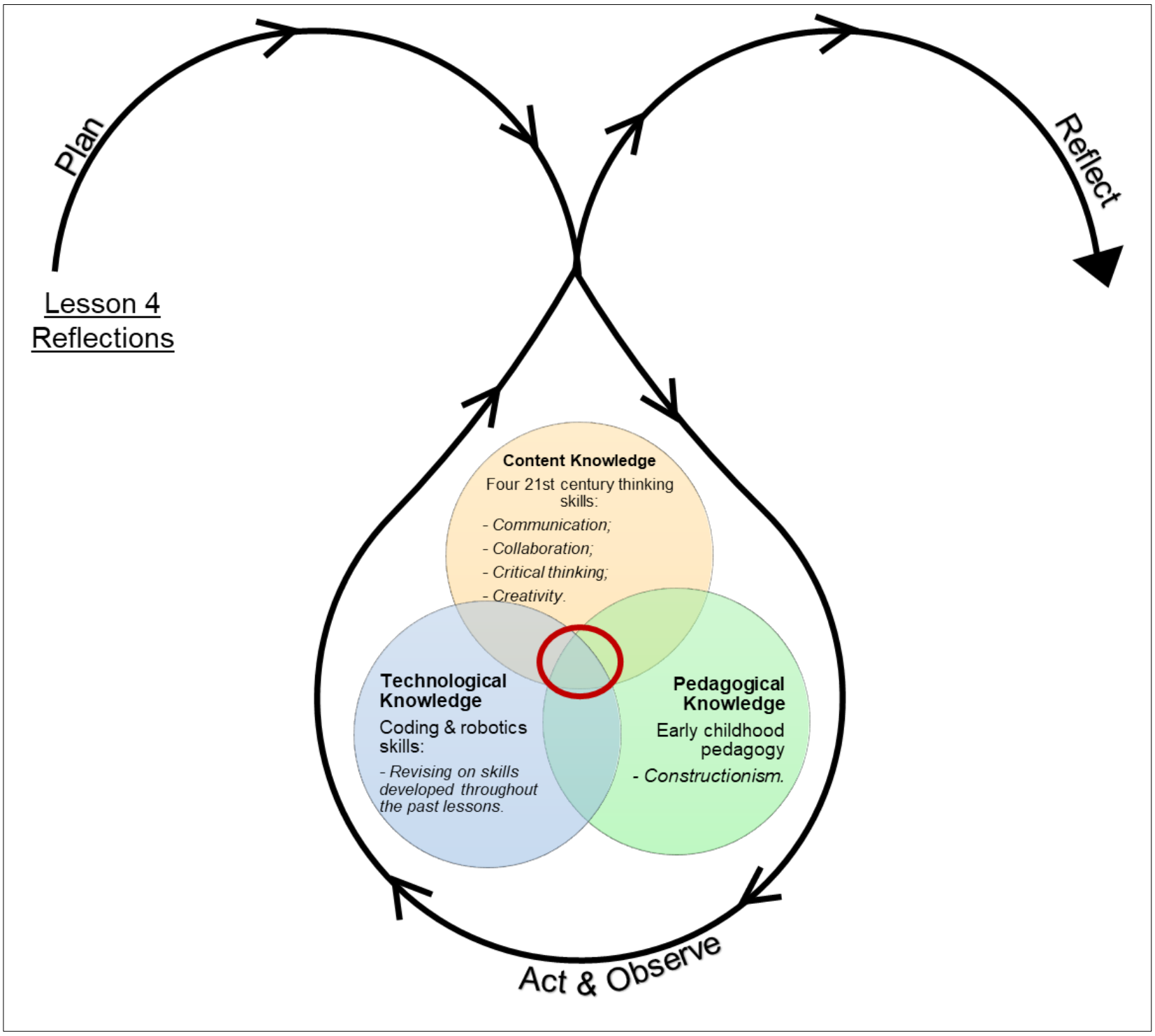


Figure 4-32: Lesson 5 Action Research process and TPACK

Figure 4.32 provides a summarised illustration of the current lesson cycle.

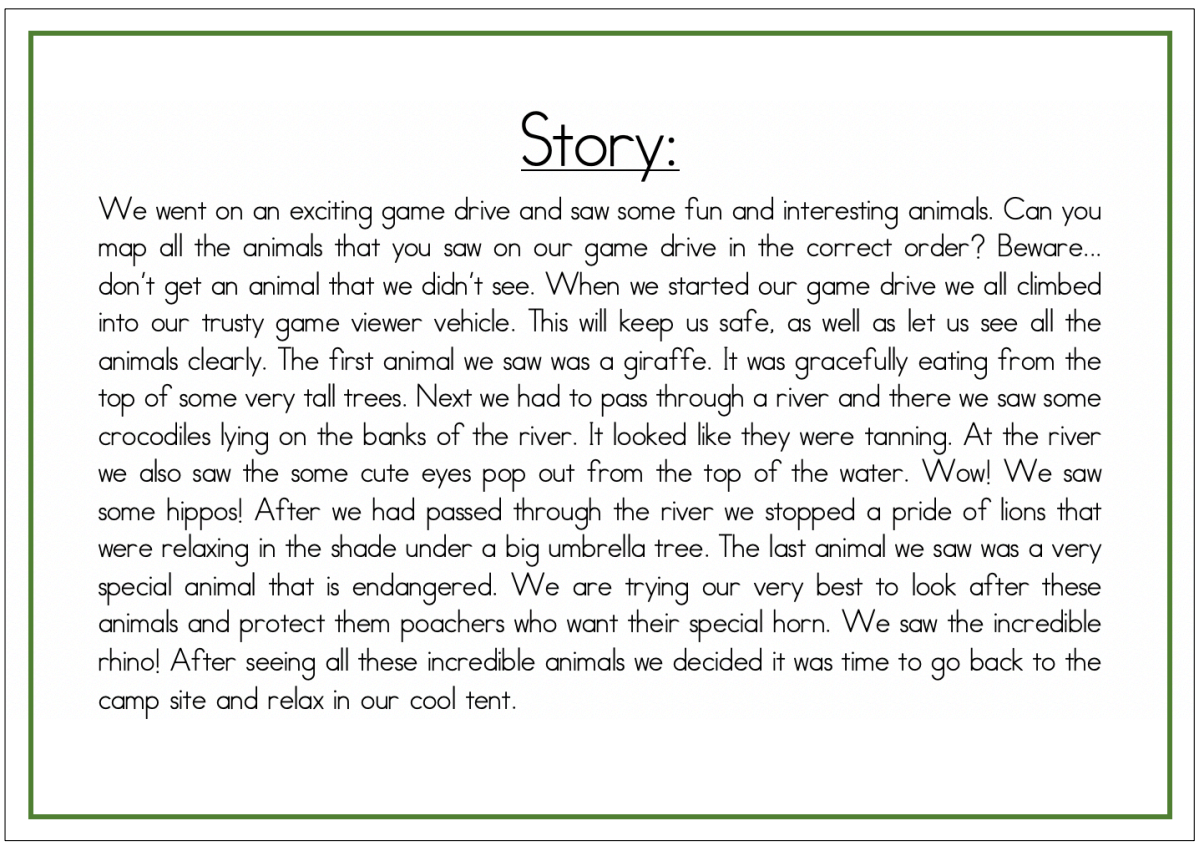
4.1.5.1 Plan

This lesson was planned using the theme of Jungle Rangers. The theme flowed throughout the lesson and encouraged the children to take on the role of jungle rangers in the Amazon Forest. The lesson aimed to revise the technological skills that were addressed in the previous lessons. Each activity in the lesson planned to focus on one or more 21st century skill.

The technological knowledge that was planned for this activity was as follows:

- The children should develop the ability to complete a grid using arrows appropriately.
- They should gain the ability to confidently manipulate the Coding Critter across a planned course/route.
- The children should be able to design and construct an object out of Lego.
- The children needed to learn to combine different pieces of 'code' (in this lesson it was considered to be beads) to construct their own.

The introduction of the lesson started as a story. The researcher immediately involved the children in a story regarding an exciting game drive and the sequence of the game drive. The children then received a grid with images of the different animals on it. The children had to draw arrows indicating where the game vehicle should go for them to see the animals in the correct sequence. The story that was given to the children is shown in Figure 4.33 below.



Story:

We went on an exciting game drive and saw some fun and interesting animals. Can you map all the animals that you saw on our game drive in the correct order? Beware... don't get an animal that we didn't see. When we started our game drive we all climbed into our trusty game viewer vehicle. This will keep us safe, as well as let us see all the animals clearly. The first animal we saw was a giraffe. It was gracefully eating from the top of some very tall trees. Next we had to pass through a river and there we saw some crocodiles lying on the banks of the river. It looked like they were tanning. At the river we also saw the some cute eyes pop out from the top of the water. Wow! We saw some hippos! After we had passed through the river we stopped a pride of lions that were relaxing in the shade under a big umbrella tree. The last animal we saw was a very special animal that is endangered. We are trying our very best to look after these animals and protect them poachers who want their special horn. We saw the incredible rhino! After seeing all these incredible animals we decided it was time to go back to the camp site and relax in our cool tent.

Figure 4-33: Story presented in Lesson 5

The children then showed their classmates their designs and evaluated each other's before showing the researcher. The children were encouraged to show the researcher their unique grids after discussing it with each other first. This promoted

collaboration and communication between the children. Figure 4.34 depicts the children discussing their unique paths on the grid.

Figure 4-34: An image of the learners engaging with one another regarding the grid in Lesson 5

The lesson was then divided into three different activities, which all followed the jungle ranger theme. The children completed the activities in groups of three. The three activities were aimed to be five minutes long and were planned to address different 21st century skills. The three activities are explained in detail below:

1. The first activity focused on the children's ability to use pieces of smaller code (beads) to construct a bigger code (their names beaded). The children were given yellow and green beads and were asked to construct their own necklaces that represented the meaning of their name. The children were given a morse code chart; they had to look carefully at the letters and, while using the correct beads for each letter, they created their names. In between each letter, they were given a silver bead to place in between the next letter. In this activity, the story was that in the amazon jungle, a treasure chest was found in the famous King Tiger Cave. The children needed to code their own names on a necklace in order to be safe from the wild animals that roamed around. Figure 4.35 depicts the children with their morse code necklaces.

Figure 4-35: Images of the learners creating their morse code necklaces in Activity 1 of Lesson 5

This activity aimed to develop the 21st century skill of critical thinking.

2. The second activity was titled ‘animal tracking’. The children were given various routes that the different animals took. The routes consisted of taped down animal prints. The children had to use a Coding Critter to track the different animals, as depicted in Figure 4.36 below. Each child received a checklist of four animals. They needed to program the Coding Critter to follow the animals tracks and to reach the animal. Once they had correctly coded the Coding Critter to reach the specific animal, the children could then check that animal off the list. The children had to work together effectively to complete the activity as they had to assist each other in following each animal’s tracks.

Figure 4-36: Learners manipulating the Coding Critter to follow the animal tracks in Activity 2 of Lesson 5

This activity aimed to develop the 21st century skills of collaboration and critical thinking.

3. For the third activity, the children were posed the task of building their own game viewer out of Lego. The children were encouraged to make their own creations; however, they were given images of game viewers for inspiration in building their own. The researcher asked open-ended questions regarding the creation, and encouraged the children to explain their creations in detail. Once completed, the children had to explain their creations to their friends. Figure 4.37 below shows the creations that the children made.

Figure 4-37: The Lego game viewers created in Activity 3 of Lesson 5

This activity aimed to develop the 21st century skill of creativity.

For the conclusion, the children were gathered around a piece of cardboard that had two lines to a jewel, as depicted in Figure 4.38 below. The children were told a story about the race to the secret lion jewel. The winner would receive the mysterious jungle prize; thus the children were challenged to get to the jewel first. They took turns coding the Coding Critter to reach the jewel first. The children were each given one turn to get the Coding Critter as close to the jewel as possible. Once their Coding Critter had stopped, their position was marked on the board by the researcher. The child whose Coding Critter was the closest to the jewel or touched the jewel was deemed the winner.

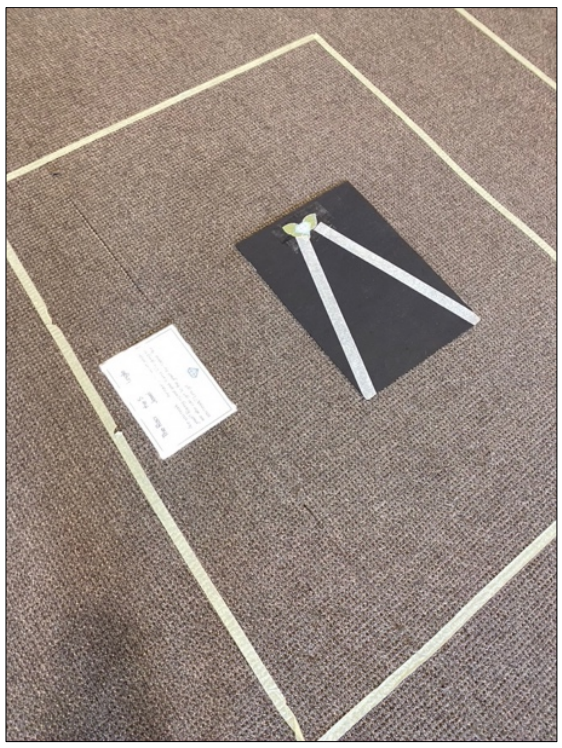


Figure 4-38: Conclusion for Lesson 5

4.1.5.2 Act and observation

Table 4.13 presents a summary of the 21st century skills development as observed during the final lesson, Lesson 5. The observation schedule for this particular lesson can be found in Appendix E. The first column in Table 4.13 states the 21st century skill being addressed. The second column is the activity section indicating the 21st century skill planned for each activity in the lesson. The second last column displays how the application of the skills was planned, and the final column provides a brief discussion.

Table 4.13: SRQ 3- Lesson 5 - 21st century skills development results

Lesson 5: 21st century skills development					
21st Century Skill	**Activity**			**How skill was planned**	**Discussion**
	1	**2**	**3**		
Communication		In the introduction		**Share own findings** with classmates before the researcher/teacher.	The children developed their communication skills in the introduction of the lesson as they were encouraged to present their own grids and compare and evaluate their grids to those of their classmates before presenting their grids to the researcher/teacher.
				Justify findings with correct terminology.	The children were encouraged to use the correct terminology when explaining the course they chose and how they designed the course on the grid.
				Communicate both verbally and in writing.	The children were verbalising their thinking when evaluating with classmates and presenting to the researcher/teacher. Then, the children communicated through written text as they drew their arrows to correctly explain their thinking process.
Collaboration		×		Collaboration through **discussion by evaluation and justification** of own findings.	The children focused on their collaboration skill in the introduction as they compared and evaluated each other's designed routes on the grid and whether these were designed with the correct animals in the correct sequence.
				Helping one another.	The second activity focused on encouraging the children to assist and guide one another when manipulating the Coding Critter to follow the route.
Critical Thinking		×	×	**Decode a code to construct their own.**	The first activity encouraged the children to build and construct their names from small pieces of 'code'. This encouraged the children to think critically as they solved the morse code to construct their names.
				Thinking critically through **trial and error**.	The second activity encouraged the children to think critically while they manipulated the Coding Critter to follow the animal tracks through trial and error. This was done without assistance.

Lesson 5: 21st century skills development					
21st Century Skill	**Activity**			**How skill was planned**	**Discussion**
	1	**2**	**3**		
				Think critically through **observation to solve a problem.**	The conclusion also focused on developing the children's critical thinking. They were given one chance to code the Coding Critter to get as close to the jewel as possible. The children got a better understanding when observing one another and thinking with a sense of measurement.
Creativity			×	**Freedom to construct** from imagination.	The children's 21st century thinking skill of creativity was developed in the third activity. The children were encouraged to design and create their own unique game viewer vehicles. This allowed the children to design however they liked. They enjoyed justifying the creation they had made with fun and useful instruments on their game viewers.

The four 21st century skills focused on in this study were observed throughout the final lesson, as with the previous lessons. The skill of communication was consciously planned into the introduction of the lesson, collaboration was planned in the second activity, critical thinking was planned for in the first two activities, and creativity was planned for in the last activity. The main observations that were discovered in this lesson were the children's ability to communicate and justify their thinking with their classmates as well as the researcher and participating teacher; the concept of trial and error was once again implemented and observed in the lesson; as well as the importance of providing the learners with the freedom to construct on their own, whether it was with physical objects or code.

Table 4.14 below summarises the coding and robotics principles developed during Lesson 5.

Table 4.14: SRQ 2- Lesson 5 - coding and robotics development results

Coding and robotics development in activities
• The children developed the ability to **complete a grid using arrows** appropriately. This skill was developed in the introduction as the children used arrows in the grid to show the route along which the game drive happened in the more complex story.
• The ability to confidently **manipulate the Coding Critter** across a planned course/route was developed in both the second activity and the conclusion.
• The children's ability to **design and construct an object out of Lego** was developed in the third activity as the children were encouraged to design and construct their own game viewing vehicle. The children were only given pictures of real game viewers to aid in constructing and creating their own game viewer. The learners used their imagination to create their own additions to the task, a game viewer. The learners enjoyed explaining their unique additions.
• The children's ability to **combine different pieces of 'code'** (in the lesson this was considered to be beads) to **construct their own** was developed in the first activity. The children used a morse code chart to construct their own name necklace. Each letter of the alphabet was given a unique code, which was constructed from two different colour beads. The children then built their names using the code for the correct letters of their names.

During the final lesson, the aspects observed were the learners' ability to complete a grid using arrows, their ability to confidently manipulate a Coding Critter, and their ability to combine different pieces of code to construct their own.

4.1.5.3 Reflect

The reflection results for Cycle 5 are given in Table 4.15 below.

Table 4.15: SRQ 1- Lesson 5 reflections

Lesson 5	**End of AR Cycle 5 reflections**
Key aspects addressed throughout the study	• The children loved having a **theme** to work with. There was great excitement for each of the activities that held a piece of the story. The theme allowed the children to move between the activities with great excitement and their imagination. • The **independent work** that occurred when building their morse code necklaces and when coding the animals to follow their tracks and the conclusion encouraged the children to think for themselves. It also created a fun, exciting and competitive nature to the lesson. • A **change in seating** occurred as the morse code necklace was completed on a table and not on the floor. The change in the environment was constructive and got the learners to settle down and engage fully in the activity. • The **story-like** introduction gave the lesson relevance and encouraged discussion, listening, and thinking from the children. • The **time** was much better managed as there were fewer activities, which allowed the children to engage in each activity to the fullest extent without feeling rushed. • The **Lego activity was a difficult one**, but this allowed the learners the opportunity to be incredibly creative. They loved the activity and enjoyed explaining it to their classmates and the researcher. • The conclusion of the lesson was a **group work activity**. It encouraged the children to all be together and cheer each other on. This was a great activity as the children were evaluating one another and discussing different ideas on how to get closer. The discussions were detailed and enthusiastic. The learners loved the competitive aspect of the activity as it got them excited and stimulated their thinking due to the time pressure. • The activities required very **little researcher/teacher intervention** and allowed the researcher and participating teacher to mainly facilitate and ask open-ended questions. This encouraged the children to think for themselves in a creative and critical way. • The **different resources/apparatus** used at each activity, provided a variety to the activities, which encouraged the children to try each station.

The most significant reflections at the end of Cycle 5 included the importance of incorporating a theme or story, the advantage of changing the seating for the children, the role of the researcher and participating teacher with little intervention, as well as the incorporation of different resources and apparatus.

4.2 CHAPTER 4 SUMMARY

This chapter presented the results of this study. The use of the Action research cycles provided the reader with the data that was relevant in the planning, acting and observation of the lessons, as well as provided detailed reflections of each

lesson. The chapter linked the data captured to the research questions posed in this study. The collection of these reflections will lead to the answer to the main research question, “How can coding and robotics support the development of 21st century skills in early childhood education?” The data collected provides a deeper understanding of each activity, and highlights the 21st century thinking skills that were implemented in each activity. The interviews also addressed the changes and development in the children’s 21st century thinking skills. This chapter presented many reflections to the reader in the form of different tables that addressed the sub-research questions that were addressed in each lesson. However the following chapter will analyse these reflections to draw their own findings and conclusions. The next chapter will present a more in-depth discussion of the sub-research questions of this study, as well as providing a suitable link to the TPACK framework employed.

CHAPTER 5 FINDINGS

5.1 INTRODUCTION

The discussions in this chapter center around the three sub-research questions and the relevant TPACK core concepts. All of the results from Chapter 4 for each TPACK concept are firstly collated in one table to allow for patterns to be revealed. High level findings for each concept are then revealed after the table, followed by a discussion thereof. This chapter will use the codes for the relevant research questions:

MRQ= Main Researcher Question

SRQ1= Sub-research Question 1

SRQ2= Sub-research Question 2

SRQ3= Sub-research Question 3

5.2 THE SUB-RESEARCH QUESTIONS

SRQ3 How can 21st century skills be developed through coding and robotics in early childhood education?

5.2.1 SRQ3 Table summary

Table 5.1 provides a comparison of all the key aspects that aided in the planning of coding and robotic activities to support the development of 21st century skills. These key aspects are then examined in relation to a qualifier that was relevant to each of the different lessons. The table also presents the number of times that each particular 21st century skill was developed in each activity across the different lessons. The tables were developed according to the four different 21st century thinking skills: communication, collaboration, critical thinking, and creativity. This discussion explores the various key aspects involved in the development of each 21st century thinking skill.

Table 5.1: SRQ3 Summary of 21st century skills presented

Summary Of The 21st century skills presented in the lessons															
21st century skills	**Activity**				**Lesson 1**		**Lesson 2**		**Lesson 3**		**Lesson 4**		**Lesson 5**	
	1	**2**	**3**	**4**	**Key Aspects**	**Qualifiers**	**Key Aspects**	**Qualifiers**	**Key Aspects**	**Qualifiers**	**Key Aspects**	**Qualifiers**	**Key Aspects**	**Qualifiers**
1. Communication	3	2	1	1	Facilitator.	Learners communicate with one another and do not depend on the researcher/teacher for all the answers.	Group work = guide their classmate.	Guide a partner who was blindfolded in the correct direction.	Group work = guide their classmates.	Learners had to use the correct terminology as well as guide their partner correctly (specifically appropriate turning terminology).	Facilitator.	The learners had to express what they wanted to do and how they wanted to do it. The learners took leadership in their own learning.	Discussions.	Learners presented their own grid, then they compared and evaluated their grids with other's before presenting it to the researcher/teacher.
					Group work = guide their classmate.	Learners guided their friend on a 5x5 grid created using square blocks of white paper. Their friend had to move across grid to collect the snake figurines.	Trial and error.	Learners encouraged to talk to one another and correct themselves through trial and error. The learners had to express themselves appropriately in order to be successful in this activity.	Discussions.	Learners verbalised the route/sequence they found on the grid and then compared unique and different routes with each other.	Learners communicated verbally and/or in writing.	The learners had to work together to decode the pictures and then they had to verbalise how they decoded the pictures to the researcher/teacher.	Justify and compare.	The learners used the correct terminology when explaining the course they chose and how they designed it.
					Discussions.	The learners discussed how the Coding Critter moved and how to follow the sequences correctly. Learners gained a better understanding. when discussing and explaining to friends.	Learners communicated verbally and/or in writing.	One learner had to express themselves in written form (by drawing the arrows on the grid), the other learner had to communicate through their actions as they had to use the Coding Critter to follow what was presented by the arrows.			Group work	Learners had to communicate with one another as they tried to solve where the jewel was hidden by reading the arrows on the sequence strip.	Communicate verbally and/or in writing.	Learners represented their thinking both verbally when evaluating and presenting their ideas, and in writing when using arrows to show their thinking.
											Justify and compare.	After listening to a story, the learners had to justify and compare their conclusions with the others.		

Summary Of The 21st century skills presented in the lessons

21st century skills		Activity				Lesson 1		Lesson 2		Lesson 3		Lesson 4		Lesson 5	
		1	2	3	4	Key Aspects	Qualifiers	Key Aspects	Qualifiers	Key Aspects	Qualifiers	Key Aspects	Qualifiers	Key Aspects	Qualifiers
2. n	**Collaboratio**	2	4	3		Group work = guide their partner.	*Learners shared ideas and built on each other's understanding. This encouraged the learners to consider one another's ideas and combine each opinion.*	*Group work = a team.*	*Learners had to solve problems and evaluate solutions as a team. Learners had to work as a team to think of a specific sequence and then when it did not work, they had to start again but adapt the sequence that was previously used to be more accurate. This activity was only successful when working together as a team.*	Group work.	*Learners were encouraged to think of new ways to manipulate the Coding Critter, and solve a problem as they worked together.*	Discussio n.	*Learners had to work together to decode the picture icons and present what they believe occurred.*	Discussio n.	*Learners compared and evaluated each other's designs as well as justifying their thinking.*
						Group work.	*Learners helped one another. They watched each other to see whether they were doing it correctly and then assisted if they needed help.*			Group work = Guide their partner.	*Working together to get the Coding Critter to move fluently as well as moving to different objects in the correct order. Learners must discuss and collaborate in order to be successful. Learners rely on one another to help and guide with reflections and suggestions.*	Group work= a team.	*Learners worked together through trial and error to get the Coding Critter to move along the pre-planned lines.*	Group work = a team.	*Learners were encouraged to assist and guide each another when manipulating the Coding Critter to follow a route.*
						Group work = a team.	*They worked together when both creating the new sequence strip and following the new sequence strip. They constantly evaluated each other as a team.*					Group work.	*Learners worked together to achieve a common goal. Learners received points each time they found the jewel correctly in a 4x4 grid.*		
						Discussio n.	*Learners created their own gross-motor sequence. They ran back and forth building the sequence and correcting one another when a tile was placed skew or incorrectly. This encouraged the learners to discuss with each other.*					*Peer evaluatio n.*	*The learners individually designed their own sequence based on a story. The learners were then encouraged to explain and evaluate others' work effectively.*		

Summary Of The 21st century skills presented in the lessons

21st century skills	Activity				Lesson 1		Lesson 2		Lesson 3		Lesson 4		Lesson 5	
	1	**2**	**3**	**4**	**Key Aspects**	**Qualifiers**	**Key Aspects**	**Qualifiers**	**Key Aspects**	**Qualifiers**	**Key Aspects**	**Qualifiers**	**Key Aspects**	**Qualifiers**
3. Critical Thinking	5	2	2	1	Facilitator	*Learners were encouraged to think for themselves.*	Planning.	*Learners reading the map had to find the quickest and easiest route for the partner to follow. Learners had to think of their own routes that were simple for another to follow.*	Design and construct.	*Learners had to evaluate the different scenarios that could occur when constructing their own sequences that they would later use to guide a friend.*	Decode to construct.	*Learners decoded a series of picture icons in order to solve what happened in the story.*	Decode to construct.	*Learners were encouraged to construct their names from small pieces of 'code' (different colour beads).*
					Explore	*This was a new activity to the learners, and it encouraged them to think critically and find their own solutions. Learners were encouraged to explore and discover.*	Trial and error.	*Learners had to constantly re-evaluate and alter the sequence they had planned in order for the Coding Critter to reach the pirate cave. The learners used problem solving through trial and error.*	Evaluate.	*They only used a Coding Critter and their minds to solve the problem. Learners had to create different scenarios for the Coding Critter to reach different objects in the correct order. Learners had to effectively evaluate different scenarios.*	Trial and error.	*Learners were not given an example and needed to discover for themselves how to manipulate the Coding Critter to follow the lines.*	Trial and error.	*Learners manipulated the Coding Critter to follow the animal tracks without assistance.*
					Design and construct	*Learners worked together to find the best route to get the Coding Critter to retrieve the treasure. They also used a pirate map as a basic grid. Learners constructed sequences for someone to follow on a grid.*	Trial and error.	*Learners had to use trial and error to manipulate the Coding Critter to effectively go around a collection of objects, something the learners had never done.*	Design and construct.	*When designing their own route on a grid, based on the story, the leaners needed to think critically and creatively, but it needed to be in the correct order that was told in the story. Other than the story order, there was no perfect or correct route.*	Evaluate.	*Learners were only given one opportunity to code the Coding Critter. Therefore, they gained a better understanding when observing one another and thinking with a sense of measurement. The learners used observation to problem solve.*

Summary Of The 21st century skills presented in the lessons

21st century skills	Activity				Lesson 1		Lesson 2		Lesson 3		Lesson 4		Lesson 5	
	1	2	3	4	Key Aspects	Qualifiers	Key Aspects	Qualifiers	Key Aspects	Qualifiers	Key Aspects	Qualifiers	Key Aspects	Qualifiers
4. Creativity	1	1	2		Facilitator	*Learners were required to design their own sequences in order to complete the task. This gave the learners their own authority to design and make their own decisions. Learners were encouraged to solve problems and think for themselves. The researchers and participating teacher's role was to merely facilitate.*	Plan and construct	*Learners were encouraged to build and construct their own designs. They had to think ahead while designing their own realistic model of a boat.*	Think for themselves.	*Learners had to be creative when building their own sequence and getting their friend to follow by telling them a story. Not only were learners thinking for themselves, they had to present it in a way their friend would understand.*	Freedom to create.	*Learners were posed with the task of designing their own key out of Lego with no assistance.*	Freedom to create.	*Learners created their own unique game viewer vehicles out of Lego. They enjoyed having the freedom to build whatever they liked and enjoyed explaining their unique additions made to their game viewers.*
									Freedom to create.	*Learners were given little guidance and were encouraged to be creative in their own designs of a horse.*	Plan and construct.	*Learners were creative while being observant of the correct order of events that occurred in the story.*		

5.2.2 Introduction to the discussion

The paragraphs in this section are separated according to the 21st century thinking skill that each addresses. The key aspects that were believed to aid in the development of these skills are written in bold below. The bold text allows for the reader to easily refer back to Table 5.1 above.

5.2.2.1 Communication

The first 21st century skill to be investigated was the skill of communication. There are multiple key aspects that were deemed to support the development of the skill of communication in young learners. One of the key aspects that was discovered related to the researchers and participating teacher's role in the lessons. The their role was that of a **facilitator**. This entailed the researcher and teacher allowing the learners to **take leadership** in their own learning by communicating with one another and exploring the presented activities. The researcher and teacher were required to observe and extend learning by asking open-ended questions. This concept was built into the design of the lessons. All of the lessons were designed to be learner-centred, and were designed with a variety of group work strategies. The learners were required to often **guide their classmates**. This was another key aspect that contributed to the development of the learners' communication skills. As seen in Table 5.1 above, the learners were required to guide their classmate to complete an activity in Lessons 1, 2 and 3. Although the activities changed and were extended, the learners were still required to effectively communicate with one another in order for the activity to be a success. This linked again to the learners' ability to **communicate verbally** as they had to verbalise the direction in which they wanted their classmates to move, all while using the correct terminology. The learners' ability to discuss their thinking and express themselves clearly to others was supported in the implementation of many of the activities. As seen in the table below, the learners were provided with many opportunities to contribute to **discussions**, whether it was about the robot or a sequence, the learners were encouraged to explain and compare their thinking. The learners' ability to communicate was again supported in their observed ability to **justify and compare** their thinking effectively with that of the other learners. The learners' ability to justify and compare was seen in the last two lessons. In Lesson 5, the learners were

required to justify their own designed sequence to their classmates, as well as present their thinking through the use of arrows. This linked to the learners' ability to communicate not only verbally, but to **communicate their thinking in writing** additionally.

5.2.2.2 Collaboration

The second 21st century skill to be investigated linked to the skill of communication was the learners' ability to collaborate with one another. Collaboration relates to the skill of communication as both skills are developed in an environment that encourages **group work**. As seen in Lesson 4, the learners were divided into groups and were required to work together to achieve a common goal, which supported their ability to collaborate. This was required because for the activity to be successful, the learners needed to be able to share their ideas with one another. Not only did they work in groups, but the learners had to work as a team. **Teamwork**, as seen in Table 5.1 above, occurred in most of the prepared lessons. The learners were required to work together as a team to solve problems, and share and build on each other's understanding of different coding and robotic principles. The activities were planned with that notion that in order for the learners to successfully achieve the desired goal of the activity, they needed to be able to communicate and listen to one another's opinions and reasoning. This was seen in Lesson 3 as the learners were required to rely on one another to help and guide each other with reflections and suggestions in order to be successful.

5.2.2.3 Critical thinking

Critical thinking is a 21st century skill that requires learners to constantly evaluate, analyse, and solve problems. Critical thinking was integrated into the coding and robotic lessons as many of the activities required the learners to think for themselves. The lessons were planned with a learner-centred approach in mind. The role of the researcher and teacher was that of a **facilitator** as in doing this, the learners were required to think for themselves. The learners' critical thinking progressed as the lessons transpired. As seen in Lesson 1, the learners were encouraged to **explore**. The exploration strategy allowed the children to create their own understanding and discover without the interference of the researcher or teacher instructing them. The learners' critical thinking skills were then further

developed through the method of **trial and error**. The method of trial and error was implemented in the remainder of the lessons. As seen in Lesson 2, the learners were given the challenge of coding the robot to move to a specific point and back. The learners were not told how to complete the task or how far away the object was, instead, through the method of trial and error, the learners had to code the robot. If this was not successful, the learners had to reassess the task and try again. The learners were required to solve problems through trial and error, which resulted in the learners constantly revaluating a problem in order to solve it. The learners' ability to **evaluate** was another key aspect that relates to critical thinking.

In Lesson 5, the learners were encouraged to observe their classmates in their attempts to get the robot to stop as close to the object as possible. The learners had to evaluate the different codes that their classmates used which were or were not successful in order to code the robot to reach the object successfully. This encouraged the learners to think critically and consider all of the different factors involved. When thinking critically, the learners were required to display their thinking process. This was displayed in their ability to **design and construct**. In Lesson 3, the learners had to evaluate the different scenarios that occurred in the storyline of the lesson and then they had to construct their own sequence that their partner would follow. This required the learners to think critically as they had to consider all of the factors involved when planning and constructing the unique sequence.

5.2.2.4 Creativity

The final 21st century skill to be investigated was the skill of creativity. The lessons were designed in a way that the learners were required to **think for themselves**. In Lesson 1 and 3, the learners were given the authority to design and make their own decisions, and think critically in their problem solving and planning. Many of the activities comprised the learners planning and constructing their own designs. As seen in Table 5.1 above, the learners were encouraged to build and construct their own boat designs. The building of their own unique boats, without assistance, required the learners to think ahead while designing their own realistic models. The learners' creativity skills were being developed as they **planned and constructed** different objects, stories, or sequences. As mentioned in the paragraphs above, the learners were given the opportunity to explore and construct their own

understanding from the different activities. The researcher and participating teacher scarcely intervened, instead, they allowed the learners to engage in meaningful learning experiences that supported the learners' **freedom to create**. Giving the learners the freedom to create whatever they desired, within the context of the activity, allowed the learners to use their imagination and required very little guidance from the researcher or participating teacher's side. The learners crafted their own unique creations - this also presented the learners with an opportunity to explain their unique creations to the researcher and the teacher, as well as their classmates. This relates to the previously discussed 21st century thinking skill of communication.

5.2.2.5 Reflection

The 21st century thinking skills were planned when designing the different coding and robotic activities. The key aspects mentioned above often assisted in the development of more than one 21st century thinking skill. For example, the key aspect of trial and error that was believed to help in the development of the 21st century thinking skill of communication was also beneficial in the development of critical thinking. The development of the 21st century thinking skills was further supported by the interviews that were held with the homeroom teachers of the learners who participated in the study. The analysis of the interviews will be discussed later in this chapter.

5.2.3 SRQ2 How can coding and robotics principles be developed in early childhood activities?

5.2.3.1 SRQ2 Table summary

Table 5.2 below presents a summary of the coding and robotic principles that were planned to be developed in the learners through the different lessons. This table helps to analyse the different learning elements, as well as the development that occurred along the different lessons as more lessons were completed. The principles increased in complexity as the learners got more comfortable in their abilities and their understanding of coding and robotics.

Table 5.2: SRQ2 Summary of the planned coding and robotic principles

Summary of the coding and robotics skills presented in the lessons			
	Key Aspect	**Qualifiers**	**Theme**
Lesson 1	Roles and responsibilities of coding and robotics class.	*Learners had to understand how to plan before acting in class.*	*Robot learning.*
	Care for the robots.	*Learning to care for the robots to ensure that the robots did not break due to misuse.*	*Robot learning.*
	Robots.	*Through the learners' own experiences, they were learning what a robot can do.* *Learners were allowed to experiment when creating their own sequences.*	*Robot learning.*
	Direction.	*Focus was placed on using the correct terminology.*	*Representation of code.*
	Grid.	*Understanding was built that one block = one step/action.*	*Foundation tool.*
	Arrows.	*Understanding was created that arrows show direction. They represented a sequence.*	*Representation of code.*
	Sequence.	*Understanding was enforced on how to read a collection of given sequence strips.*	*Representation of code.*
Lesson 2	Robot.	*The Coding Critter was used in different ways to gain a basic understanding of what the robot could do and how to manipulate it. Learners solved through trial and error.*	*Robot learning.*
	Direction.	*Learners learned the terminology and meaning of the directions.*	*Representation of code.*
	Grid.	*With more independence, the learners understood that one block is equivalent to one step or action.*	*Foundation tool.*
	Sequence.	*Learners began to understand how to correctly construct their own sequence and the different factors to consider.*	*Representation of code.*
Lesson 3	Terminology.	*Learners used correct terminology when guiding their friend to turn.*	*Representation of code.*
	Sequence.	*Learners focused on developing their own sequence to solve a problem or guide their partner to complete the task.* *Learners were required to plan and consider all of the factors while creating a sequence.* *When constructing their own coding sequence, they had to be creative in their own thinking, as well as having the correct outcome.*	*Representation of code.*

Summary of the coding and robotics skills presented in the lessons			
	Key Aspect	**Qualifiers**	**Theme**
	Robot.	*Learners used the correct terminology but were also able to manipulate the Coding Critter to turn around.*	*Robot learning.*
	Grid.	*Learners focused on discovering a route in a grid using arrows. Learners constructed the sequences in a grid, as well as moving around obstacles in the grid*	*Foundation tool.*
Lesson 4	Grid.	*Using a 4x4 grid made out of blocks of printed paper, the learners followed arrows on a sequence strip to discover an object hidden in the grid. They then changed the cards to create their own grid and draw arrows for their friends to follow.* *Learners compared their grids with those of their classmates and evaluated one another's grids.* *Learners drew their own arrows on a grid to represent the route/order/sequence of the story told.*	*Foundation tool.*
	Robot.	*Through trial and error, learners focused on manipulating the Coding Critter to follow a pre-planned course (lines). Learners used more buttons in different sequences and longer sequences.*	*Robot learning.*
Lesson 5	Grid.	*Learners drew arrows in a grid to show the route/order/sequence of a more complex story.*	*Foundation tool.*
	Robot.	*Learners focused on manipulating the Coding Critter across a planned course/ route.*	*Robot learning.*
	Constructing.	*Learners were only given pictures of real game viewers to aid in constructing and creating their own game viewer out of Lego.*	*Foundation tool.*
	Pieces of 'code'	*Learners built their names using the code (different colour beads in patterns) for the correct letters of their names. Learners had to understand the morse code sheet in order to successfully 'code' their own names.*	*Representation of code.*

5.2.3.2 Introduction to the discussion

The lessons were presented to early childhood learners. Therefore, the manner in which the lessons were presented, as well as the content of the lessons, was selected for the young age of the learners. The lessons focused on allowing the learners to construct their own understanding through experiences and repetition. The learners were also encouraged to work in pairs or groups, this also played a role in their learning as they had to discuss their thinking with other learners. Each of the coding and robotics principles that were developed in the lessons started as simpler activities that became more complex as the learners completed more lessons. As seen in Table 5.2 above, there were key aspects that were repeated throughout the different lessons. These key aspects will be discussed in detail below and combined in regard to the different themes that were covered in the summary table above. The key aspects are written in bold, which will allow for easy referral to the summary in Table 5.2. The discussion will be divided into paragraphs that focus on each relative theme.

5.2.3.3 Robot learning

The first theme discussed, which is a major component of coding and robotics, is **robots**. As seen in Lesson 1, the learners started their very first lesson learning about how to **care for the robots** while having the opportunity to explore and learn about what the robot is capable of doing. As the lessons continued, the learners' understanding and ability to manipulate the robot progressed, which allowed for the activities be more structured and task-orientated. As seen in the very next lesson, Lesson 2, the learners were required to use the process of trial and error to get the robot to complete a simple task. As seen in Lesson 3, these tasks grew in complexity as the learners were required to get the robot to turn around. Then, in Lesson 4, the learners were encouraged to manipulate the robot to follow a pre-planned course. The learners' understanding of robots developed through each lesson as the designed activities continued to encourage the use of more buttons and longer sequences.

5.2.3.4 Representation of code

The second discovered theme relates to the key aspects associated with the representation of code. A further key aspect that was discovered is the learners' understanding of a **sequence** of code. The sequence strips consisted of a collection of **arrows.** In Lesson 1, as seen in Table 5.2 above, the learners grasped the concept that the arrows show **direction**. Their understanding of direction was implemented through the use of arrows and guiding another learner, first in a gross-motor sense and then later with the use of different resources. When discussing direction, the learners were constantly reminded in each lesson to use the correct **terminology**. As seen in Lesson 3, the learners were required to use the correct terminology when guiding their friend to turn. In Lesson 1, the learners were also taught how to read sequence strips that comprised different arrows. The one activity in Lesson 1 consisted of different floor tiles, which had arrows, as well as action tiles. The learners had to follow the sequence that was presented on the floor. The other activity in Lesson 1 that encouraged the understanding of a sequence strip was a strip of arrows that the learners had to read and then replicate on the robot. The learners first learnt to read and understand the sequence strips. This progressed to encouraging the learners to construct their own sequence and to guide another learner, as seen in Lessons 2 and 3. The learners were motivated to consider other factors that would influence the sequence, such as particular events that occurred in the story. The consideration of these other factors resulted in the learners planning the sequence, and thinking creatively and critically in their planning.

5.2.3.5 Foundation tool

The foundation tool theme relates to what the learners were exploring on a basic level of understanding with regard to coding and robotics. The next key aspect is a foundation tool that focused on the learners' understanding of **grids**. The concept of grids was first taught through a grid that was taped to the floor. The young learners were required to use their bodies to move along the grid. As seen in Lesson 1, and in Table 5.2 above, the lesson focused on teaching the learners that one block represents one step or one action. This concept was repeated in the following lessons. In Lesson 3, the learners were then encouraged to manipulate themselves

around a grid but to also move around different obstacles that were present in the grid. The learners no longer needed to follow a simple sequence on a grid, but were encouraged to discover routes on a grid and compare their own routes to those of their classmates. As seen in Lesson 4, the learners were required to first follow a simple sequence to discover an object hidden behind square blocks of printed paper. Then, the learners took turns hiding the secret object and constructing their own sequence strips for another learner to follow around the grid in order to discover the secret object. The grid changed from a grid taped to the floor to pieces of printed paper cut into squares, to a grid printed on an A4 sheet of paper. The use of different mediums allowed for the learners to develop their understanding through multiple experiences.

5.2.3.6 Reflection

These key aspects all led to the development of different coding and robotics principles. These were subject to the development of the specific young learners involved in this study, and their understanding and abilities. As seen in Table 5.2, the first lesson focused on understanding the concept of coding and robotics, and allowing the learners to explore using different resources. However, as the learners progressed, the lessons started integrating more instructions and factors that the learners were required to consider when learning about the different coding and robotics principles present in the activities.

5.2.4 SRQ1 How can coding and robotics activities be set up to best support development in early childhood education?

5.2.4.1 SRQ1 Table Summary

Table 5.3 below provides a summary of all the key reflections from the five lessons. The table highlights common factors that recurred throughout the lessons, and reflections that were deemed to be helpful in the planning of coding and robotics activities for early childhood learners. These reflections led to the development of a set of guidelines that will ultimately assist future teachers in the planning of coding and robotic lessons to develop learners' 21st century skills. Each lesson reflected on the activities and found key observations that impacted the lesson. These reflections were implemented in the planning of the next lesson. Therefore, not every lesson

had the same reflections, however, all of the reflections ultimately impacted the study as a whole as they played a role in the planning of the consecutive lesson.

The right column of the table highlights recurring themes to which the key aspects related. This will assist the reader as these themes are discussed later in the study.

Table 5.3: SRQ1 Summary of the key reflections

Summary of the reflections in the lessons			
	Key Aspect	**Qualifiers**	**Theme**
Lesson 1	Discussions.	The children were too enthusiastic to move between activities, no calm discussions occurred.	Nature of activity.
	Work in pairs.	Learners were encouraged to collaborate and communicate to work effectively together.	Nature of activity.
	Learner-centred.	Activities designed for learners to communicate regarding their opinions and allowed the researcher and participating teacher to take on facilitating role in the classroom.	Nature of activity.
	Time.	Learners were rushed to finish activities. Therefore, it is important to set aside a few minutes before or after each activity to allow the children to play with the apparatus and tools at each activity station before moving onto the next one.	Time management.
	Creativity led.	Learners were not comfortable being creative. It is important to provide learners with more opportunities to be creative.	Activity level.
Lesson 2	Theme.	Learners loved using their imagination to complete a task. The theme gave context to what they were required to do in a fun way.	Lesson design.
	Storyline.	This provided the learners with a background and plan for each activity that was fun and held their interest. Each activity had its own story line that allowed the learners to get involved and start drawing their own conclusions.	Lesson design.
	Number of activities.	The learners rushed between each activity as they were excited to engage in each activity. Instead, the lesson should contain fewer activities, or the duration of the activities should be shorter. This will allow the children to engage in each activity without feeling rushed or overwhelmed, or that they may possibly be left out.	Time management.
	Time.	Timer used. This helped with time management as the learners knew they could not move on from an activity until the time was up and they could not stay at their favourite activity. Using the timer gave the children authority over their own completion of the activities.	Time management.

Summary of the reflections in the lessons			
	Key Aspect	**Qualifiers**	**Theme**
	Concrete apparatus.	The use of more concrete apparatus allowed the learners to engage in each activity to discuss and ask questions.	Lesson design.
	Level of difficulty.	Learners rushed easier activities in order to play. This should be better managed so that the lesson is evenly split between activities of similar duration.	Time management.
Lesson 3	Theme.	The implementation of the themes allowed the children to develop 21st century skills as they communicated regarding the storyline; they collaborated to solve a relevant problem; they were creative regarding the theme and building something relevant to the theme; and they thought critically of different scenarios in the correct context.	Lesson design.
	Time.	Used a timer. This was effective as it allowed the children to complete all of the activities. However, they did not get time to play, therefore more time is needed, and the activities need to be equal in duration.	Time management.
	Check off activities.	A resource was used for learners to check off different activities. It was effective for some of the children, however, the children wanted to focus more on the activities instead of checking them off.	Time management.
	Group work.	Larger groups allowed the children to discuss interesting routes/scenarios with more classmates, and to correct each other without the intervention of the researcher or teacher.	Nature of activity.
	Designated activities.	Each activity focused on one or more 21st century skill.	Activity level.
Lesson 4	Theme.	Learners could construct their own adventures.	Lesson design.
	Storyline.	Learners fully were immersed in the scenario and started thinking relative to what happened in the story. There was a purpose for the task that the learners completed.	Lesson design.
	Level of difficulty.	Researcher and participating teacher should be aware of the level of difficulty when planning activities, especially creative ones, and should ensure that it is not too easy.	Activity level.

Summary of the reflections in the lessons			
	Key Aspect	**Qualifiers**	**Theme**
	Time.	It is important to ensure that the activities have the same duration. It was easier with fewer activities. Also ensure either more time for activities, activities that take longer, or more activities. This would mean that learners are engaged in an activity for the full duration of the lesson.	Time management.
	Group work.	The changing of the groups from pairs to groups of three allowed the children to communicate with someone else as well.	Nature of activity.
Lesson 5	Theme.	There was great excitement for each of the activities which held a piece of the overarching storyline of the lesson. The theme allowed the children to move between the activities with great excitement, and caused them to use their imagination.	Lesson design.
	Independent work.	This activity encouraged the children to think for themselves, as well as creating a fun, exciting, and competitive nature to the lesson.	Nature of activity.
	Seating.	The change in environment from the floor to the table was productive and got learners to settle down and engage fully in the activity.	Lesson design.
	Storyline.	The storyline gave the lesson relevance and encouraged discussion, listening, and thinking from the children.	Lesson design.
	Time.	Fewer activities allowed the children to engage in each activity to the fullest extent without feeling rushed	Time management.
	Level of difficulty.	The Lego creative activity was difficult and gave the learners the opportunity to be incredibly creative, and explain their unique designs and creations.	Activity level.
	Group work.	Working in groups encouraged the learners to constantly evaluate one another and discuss different ideas. The discussions were detailed and enthusiastic, and they learnt from each other's mistakes. The learners loved the competitive aspect of the activity. It got them excited, and motivated them to think under a time pressure.	Nature of activity.
	Learner-centred.	The activities were learner-centred. The researcher had to mainly facilitate and ask open-ended questions. This encouraged the children to think for themselves in a creative and critical way.	Nature of activity.

Summary of the reflections in the lessons		
Key Aspect	**Qualifiers**	**Theme**
Concrete apparatus.	The learners were provided a variety of different concrete resources for the activities, which encouraged the children to try each station.	Lesson design.

5.2.4.2 Introduction

The purpose of this in-depth discussion is to answer the research sub-question, 'How can coding and robotics activities be set up to best support development in early childhood education?' This question is addressed in the discussion that follows. This is done by highlighting the key aspects involved in the coding and robotics activities that were deliberately planned in this study for early childhood learners. The words in bold found in the discussion below refer to the key aspects found in Table 5.3 above.

5.2.4.3 Nature of the activity

The first theme addressed in this discussion focuses on the nature of the activity. The nature of the activity theme focuses on key aspects that contributed to the disposition of the activities and how the activities were designed. From Lesson 1, the activities aimed to be **learner-centred**. This means that the lessons were planned to encourage the learners to construct their own understanding. The lessons were designed in a way that encouraged **group work**, which led to insightful **discussions**. As seen in Table 5.3 above, starting with Lesson 1, the lessons were designed to encourage communication and collaboration between the learners. This meant that the researchers and participating teacher's role was to merely facilitate as learning took place. This thinking continued again in Lesson 3 as larger groups were formed, which created opportunity for more discussions and debates to occur between the learners. This solidified learning as the learners explained and verbalised their thinking, as well as subconsciously evaluating their thinking against that of their classmates. This same strategy of group work occurred in Lesson 4 as all of the groups were rearranged, which encouraged learners to work with another individual who thought differently. Lesson 5 planned both group activities, **independent work**, and whole-class activities. The change from group work to independent work encouraged the learners to think for themselves, but the aspect of group work was always a constant in the previous lessons. Therefore, when the activity was completed, the learners were found discussing and reflecting on the activity with their classmates subconsciously. The whole-class activity was one of the highlights of the lesson as the learners observed and motivated one another, passing on pieces of thinking or advice that could assist in solving the problem

presented. This created a loving yet competitive atmosphere to the lesson. Throughout all of the lessons, the role of the researcher and participating teacher was to merely facilitate and ask open-ended questions that extended learning or subtly guided the learners' thinking.

5.2.4.4 Time management

Time management, which was a recurring theme, links to the effective use of time in the lesson. The key aspect that was found to have importance from the very first lesson to the last lesson was the aspect of **time**. Immediately from the first lesson, it was discovered that time played a role in the atmosphere of the lesson. If it was not managed well, the lesson felt hurried. In Lesson 2, it was revealed that the **number of activities** impacted how time was used in the lesson. The researcher reflected on and constantly considered whether the learners engaged in the activity, whether they were rushing, or whether they were playing. In order for time to be well managed, it was suggested that there time be planned for each activity, as well as a bit of time to play and explore the resources of each activity. In this lesson, a timer was also used. The use of the timer gave the children authority over the completion of each activity as they had to be stationed at that activity until the time was completed before being able to change activities. An alternative time management strategy that was used was a check-off list in Lesson 3. This was not as successful as the timer as the learners were not interested in checking off the activities, instead, they focused more on the activity, which was a desired attitude. Another aspect that was found to have an impact on time management was the **level of difficulty** of the activities. As discovered in Lessons 2, 4 and 5, the learners were eager to complete the easier activities quickly in order to have time to play with the activity's resources. Although play is an element of early childhood education, it was distracting for the learners during the other, more complex activities. Therefore, the solution is to plan all of the activities to have a similar level of difficulty as this will manage the time spent at each activity, and ensure that the time is constructive and engaging.

5.2.4.5 Activity level

The activity level of the lessons is regarded as another important theme as the key aspects that focus on the design and difficulty of the activities were frequently discussed during the research. The previously discussed key aspect of the **level of**

difficulty impacted the planning of activities, not just the time management thereof. As seen in Table 5.3 above, in Lesson 5 it was noticed that the level of difficulty for the creative activity was difficult, and this created an opportunity for discussions about the learners' unique creations. This links to the development of not only creativity, but also communication and collaboration as they discussed their thinking and creation with others. Therefore, the planning and designing of activities to support these skills is valuable. As depicted in Lesson 1, and seen in Table 5.3 above, the learners were not comfortable having the freedom to be creative. Therefore, it was important to provide learners with **creativity-led** opportunities in the following activities for the learners to be creative. This aspect was supported in Lesson 3 where it was planned that each activity should focus on one or more 21st century thinking skill. This **designated activities** thus incorporated specific 21st century skills in each activity. This ensured that each skill was addressed in the lesson at least once, and ultimately provided the learners with opportunities to enhance these skills. This was an overarching aspect to the design of each activity.

5.2.4.6 Lesson design

While the design of the activities plays a crucial role, the design of the lesson as a whole is also important. It is important to design lessons that are engaging for young learners. From Lessons 2 to 5, the lessons were planned in accordance with a particular **theme**, which changed with each lesson. The use of a theme in the lesson was a great initiative that encouraged the learners to use their imagination when completing the activities. The themes were: pirates; western; detectives; and game rangers. Not only did the implementation of a theme encourage the learners' imagination, it also created a specific context for the activities. This links to another key aspect, the use of a **storyline**. The use of a storyline provided the learners with a background to, and the relevance of the activities in a fun and creative manner. As seen in Table 5.3 above, there were great advantages to using a storyline. In Lesson 2, it is believed that the storyline allowed the learners the opportunity to get involved and start drawing their own conclusions. In Lesson 5, the use of a storyline was believed to have encouraged discussion, listening and thinking in the learners. The combination of activities with a theme and storyline is believed to support the development of 21st century thinking skills. In Lesson 3, the implementation of the

theme (of detectives) and the storyline were thought to strengthen the learners' communication skills as they discussed the storyline.

The learners' collaboration skills were developed as they worked together to solve a relevant problem. Moreover, their creative skills were developed through building something in accordance with the theme. Lastly, their critical thinking was developed as they were required to think critically of different scenarios that could have happened in the story's context. Both the planning of a theme or storyline and the use of appropriate resources had an impact on the lesson design. The use of **concrete apparatus** is believed to have an impact on young learners' learning. As seen in Table 5.3 above, in Lesson 2, the use of concrete apparatus allowed the learners to engage in each activity by discussing and asking questions. Not only did the use of concrete resources allow the learners to engage in the lesson and use a variety of thinking and communication skills, but in Lesson 5, it was seen that the use of concrete apparatus also encouraged the children to try each activity. This relates back to the finding that the learner is given authority over their own learning when the lesson is presented in an engaging and interesting manner.

5.2.4.7 Reflection

The above-mentioned themes were discovered and evaluated throughout the study. After each lesson, the researcher observed and reflected on each lesson that was presented before planning the next. This aided in ensuring that these themes were repeatedly considered throughout the cyclical process of each lesson, which included the planning, acting, observing, and reflecting thereof. The implementation and discovery of these themes appeared to have produced a beneficial impact on the early childhood coding and robotics lessons.

5.2.4.8 Interviews

The researcher attained primary and secondary findings based on the formulated research questions to address the aims of this research. Further primary findings are detailed below, while the detailed interview schedules are available in the appendices. Although these interviews provide quantitative data, the data is used to support the qualitative findings. Two interviews were held before the lessons took place, and another two interviews were held after the lessons were conducted. The first

interviews allowed the homeroom teachers of the children to address their understanding of the concept of coding and robotics, as well as that of 21st century thinking skills. The homeroom teachers were also requested to provide each of their learners with a score for each 21st century skill, which was compared to the interviews that were held five weeks later. A score was awarded to each child per 21st century skills according to what the homeroom teacher believed the learner displayed in the homeroom classroom environment. the first interview as held and scores were captured before the coding and robotic lessons took place. In this time, the learners were attending coding and robotics lessons once a week. The teachers were asked to reflect on the learners in their class. After our first interview, the homeroom teachers were more aware and had a better understanding of coding and robotics, as well as the different 21st century thinking skills. The teachers were asked to evaluate the skills in each of the learner participants once again.

Figure 5.1 below compares the findings from the first and second interviews. The homeroom teachers evaluated each of the participants' communication skill on a scale of zero to five. The teachers evaluated the learners' skills in the first interview, and then after the lessons took place, six weeks later. As supported by the graph below, the teachers felt that there was a significant improvement in the participants' communication. This is supported in the second interview as one of the participant's homeroom teacher explained, "Before, she was incredibly chatty but not focused. Whereas now she is way more focused. She communicates a lot better. When she thinks of topics first before asking and talking about it." This supports the researcher's belief that the 21st century skill of communication is developed in coding and robotics lessons. Another teacher stated in the interview,

> *I think it's been incredibly beneficial for him. He was actually quite quiet and quite withdrawn. And he's really sort of come out of his shell. Think it's really good… And he would get really excited when he knew it was coding day. So it really helped him a lot, I think. A massive improvement.*

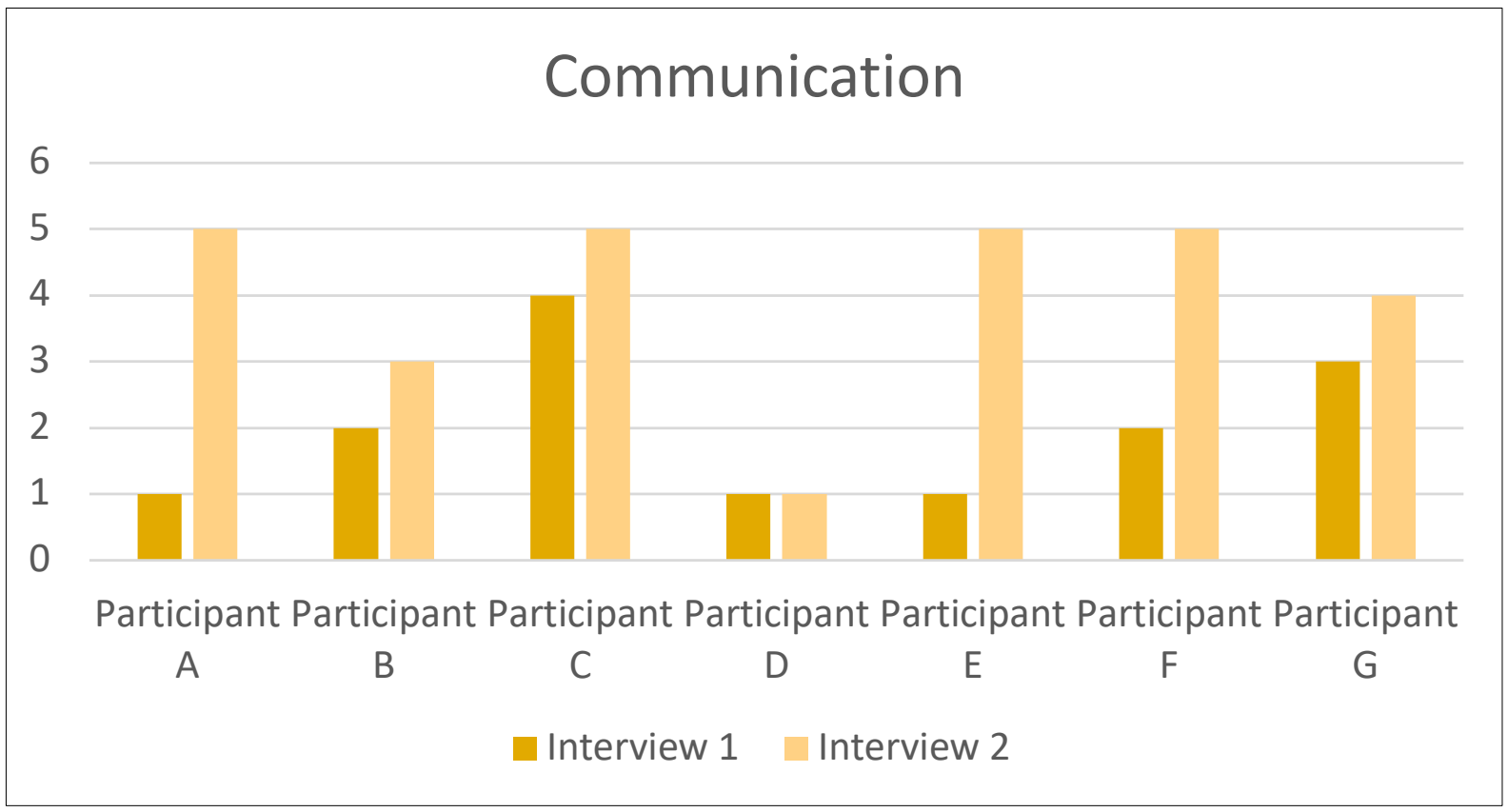


Figure 5-1: Comparison of the development of the participants' communication skill before and after the lessons were presented

As seen in Figure 5.2 below, there has been a significant improvement in the learners' collaboration skill, as seen in the comparison of their skill level before and after the lessons were held. However, it should be noted that one learner's skill stayed the same, which was already significantly high to begin with. However, all of the other learners showed an improvement in their collaboration skills. In a discussion regarding the participants' skill level, the homeroom teacher stated, "Before not great, I said a two, but a lot better now, probably a four."

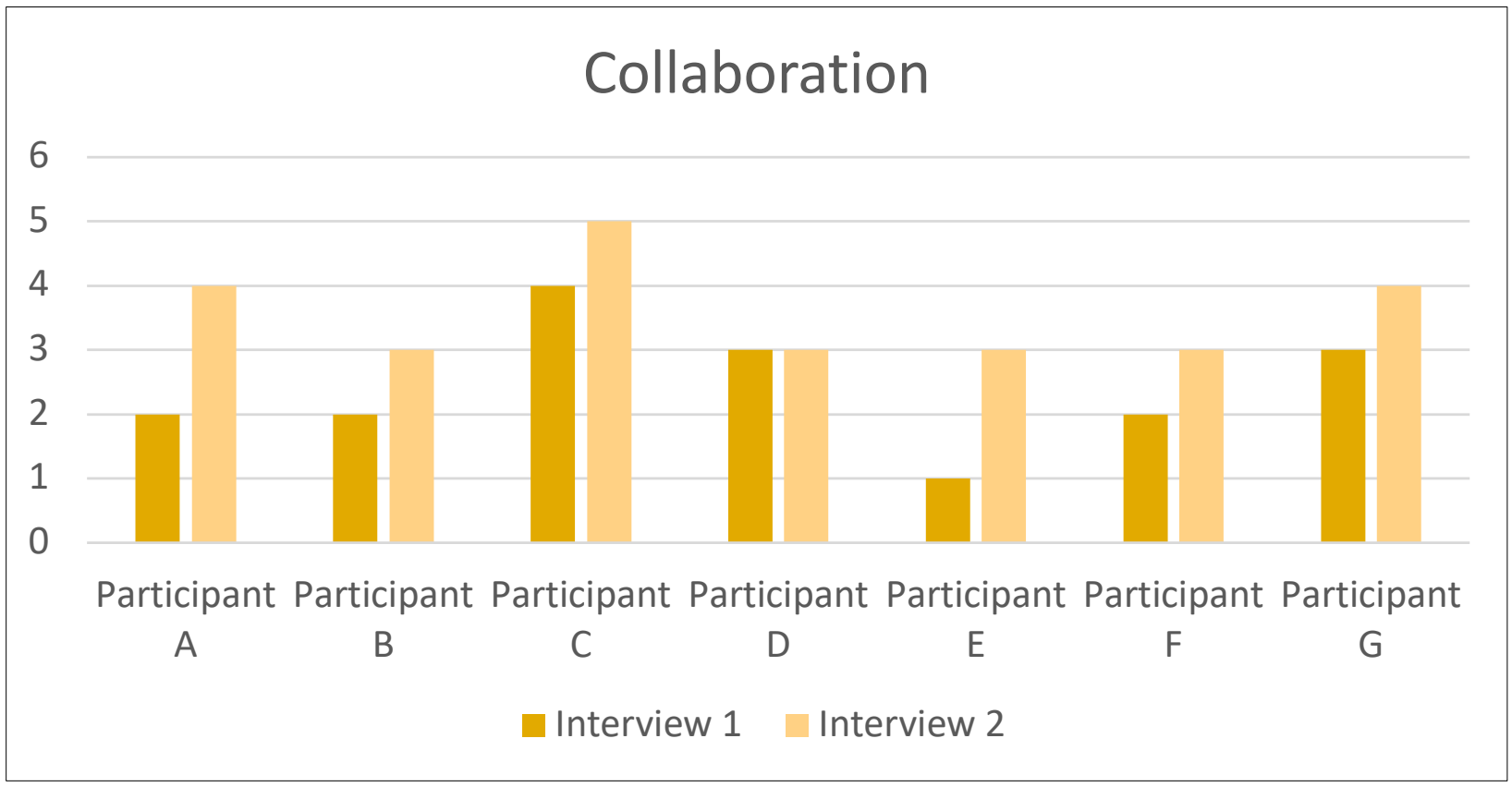


Figure 5-2: Comparison of the development of the participants' collaboration skill before and after the lessons were presented

The 21st century skill of critical thinking showed the same trend as that of the previous two 21st century skills analysed. As depicted in Figure 5.3 below, there was an improvement in most of the learners. With regard to critical thinking, two learners remained the same, however, they were already given a fairly high score from their teacher to begin with. Across the different participants, there was a significant change in the evaluation of the learners' critical thinking skill after the lesson took place, as their skill level was rated as fairly high. The lowest scores were marked as three out of five, however, four participants were given a full score. One teacher stated in the interview, "Her critical thinking as non-existent so a one, but maybe average now, so a three." The homeroom teacher explained that this learner had previously displayed a very low level of critical thinking skills, however, after the lessons took place, this learner was at a similar level to that of other children her age.

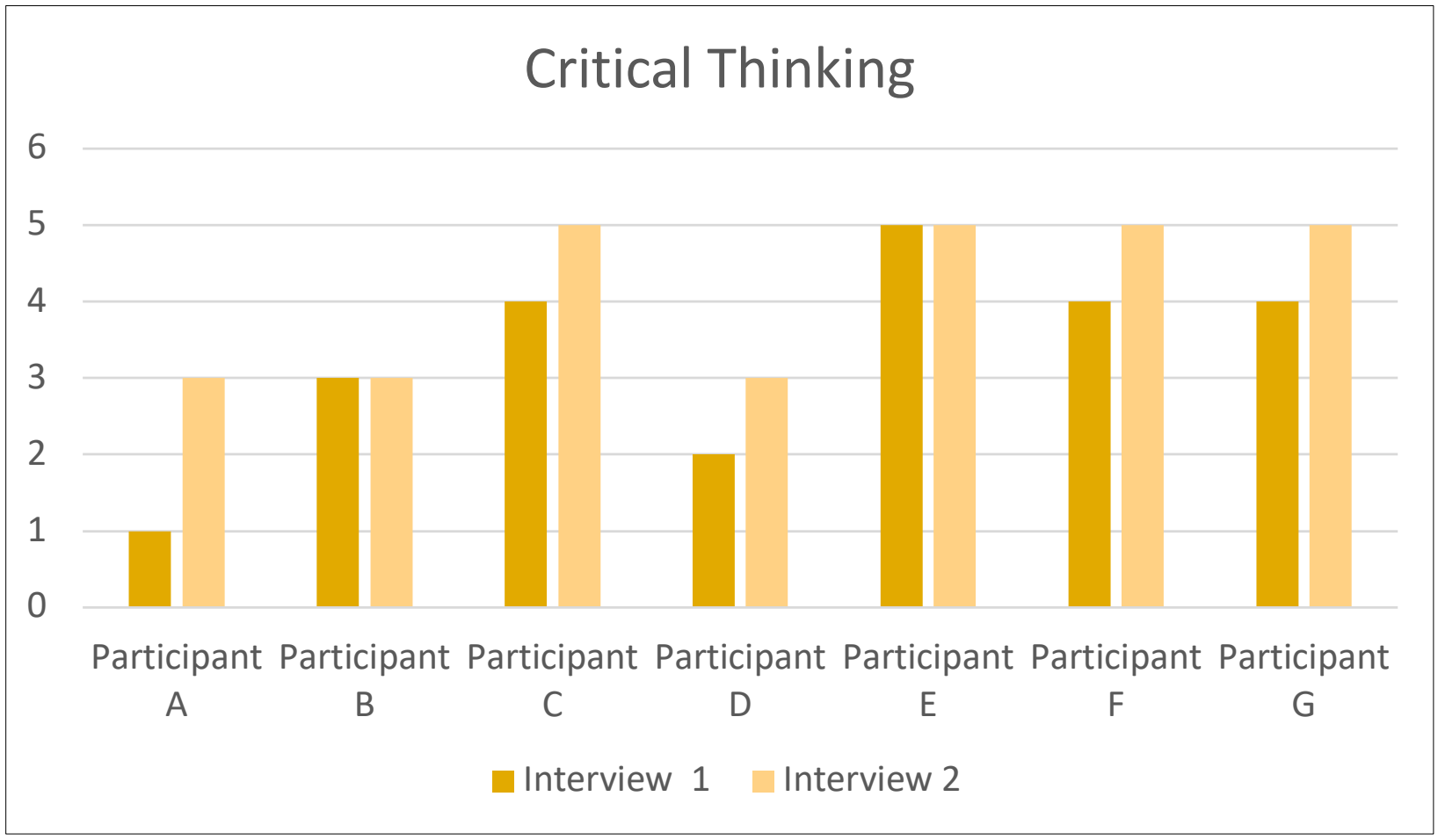


Figure 5-3: Comparison of the development of the participants' critical thinking skills before and after the lessons were presented

As presented in Figure 5.3 above, five of the seven participants showed an improvement in their creativity, and scored relatively high scores after the implementation of the lessons. With regard to the seven participants involved in the study, four of the participants scored five out of five in the second interview that was held. In Figure 5.3, it was seen that the participants'' 21st century skill of creativity either remained the same or improved after the lessons were held. One teacher said,

> *Creativity is difficult with him. If it is something concrete, he is very creative, but not if it's fantasy or imagination, like when we created robots in first term, he was very creative. He even put glitter gel in the top that was given his brain. But when he does to art and stuff he is off the wall. So I think coding was very good for him. Because he was doing that creative aspect that he enjoys, like building and planning. So I would say he ended with a four.*

This homeroom teacher noticed a significant improvement in the learner's ability to be creative, and she believed that the lessons were responsible for this improvement.

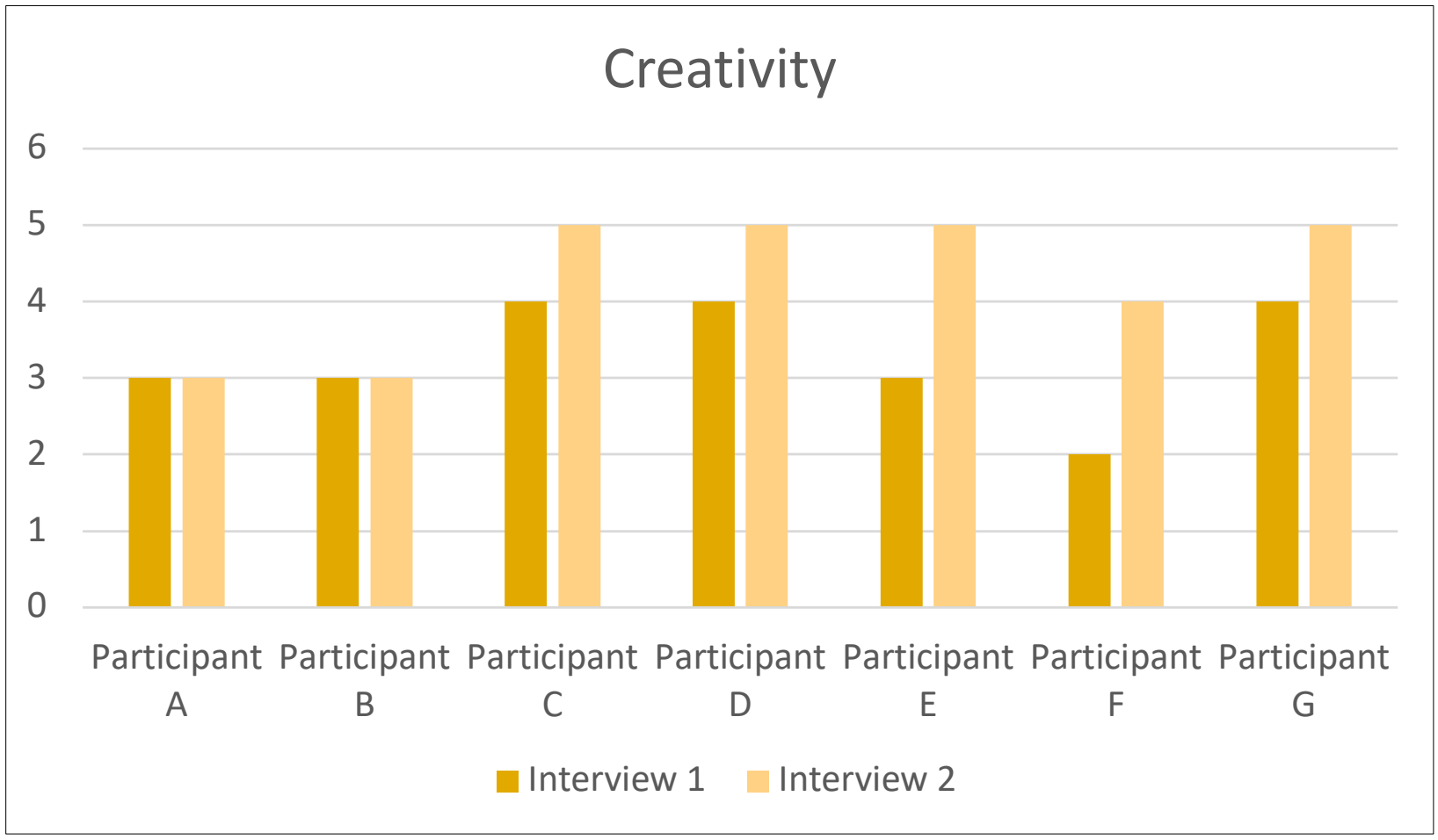


Figure 5-4: Comparison of the development of the participants' creativity skills before and after the lessons were presented

5.3 CHAPTER 5 SUMMARY

This chapter provided an in-depth analysis of the three sub-questions posed in this study. This was done in order to answer the main research question of this study. This chapter noted the themes and trends that recurred throughout the different lessons, and the impact they had on the learners' development of 21st century thinking skills in coding and robotics activities. Chapter 6 will provide the reader with a deeper understanding of the connections between the research questions investigated and the TPACK framework utilised in this study.

CHAPTER 6 CONCLUSIONS

6.1 INTRODUCTION

This study aimed to gain a deeper understanding of how coding and robotics support the development of 21st century skills in early childhood education. The study investigated three questions that would aid in answering this. The study also aimed to develop principles that can assist with planning coding and robotics activities to support the development of 21st century skills. In this study, all of the findings were linked to 21st century skills by examining the development of these specific skills during the coding and robotics activities. The participants' homeroom teachers were also interviewed regarding their observation of the learners' development of 21st century skills. This chapter will consolidate the findings presented in the previous chapter. Chapter 5 analysed the key aspects discovered and associated these with the recurring themes. These findings will be presented with the use of cluster diagrams and discussions, which will allow the reader to gain a deeper understanding of the connections between the research questions that were investigated. The findings presented in these cluster diagrams were investigated in accordance with the literature discussed in previous chapters. The purpose of investigating the sub-questions was to find any patterns that were common throughout the observational data. This was done with the goal of interrogating the main question, "How can coding and robotics support the development of 21st century skills in early childhood education?"

6.2 SUMMARY OF THE FINDINGS

6.2.1 SRQ1 How can 21st century skills be developed through coding and robotics in early childhood education?

In this study, the 21st century thinking skills were a major factor considered in the planning of the activities. Each activity aimed to develop at least one or more of these skills. The findings of this study support the relationship between 21st century thinking skills and coding and robotics activities. As seen in the interviews with the homeroom teachers of the children who participated, there was a clear overall improvement in the learners' development of 21st century thinking skills after the

lessons had taken place. As depicted in Figure 6.1 below, the four 21st century skills were combined to show the connections that occurred between the key factors in this study, and the multiple times throughout the different lessons that the different skills occurred. The colours selected to represent the different key aspects were randomly generated.

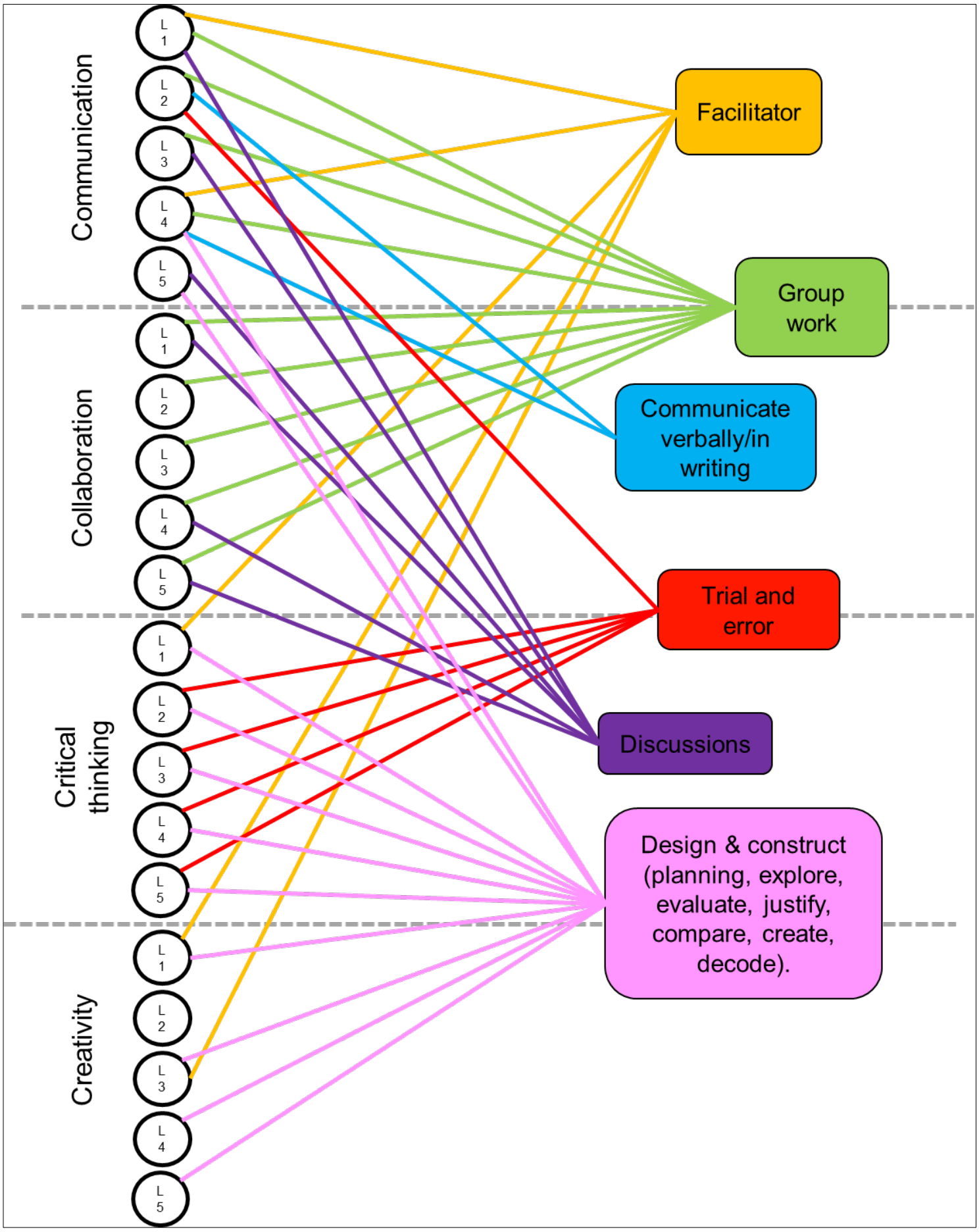


Figure 6-1: The key aspects that impacted the development of the 21st century skills

The first 21st century skill to be discussed is the skill of communication. In this study, the development of the children's communication and collaboration was a natural process as the activities were planned to consist of small groups or moments of reflection. As illustrated in Figure 6.1 above, **group work** played a significant role in nine of the planned activities, and was still implemented in three other activities. The children were regularly encouraged to reflect on their findings with their friends or to work together to reach a common goal, this agrees with literature that defines the 21st century skill of communication as the development of self-expression (Hobbs & Frost, 2015). The children in this study were given the chance to develop this skill when presenting their reflecting on the grid findings to the class, or when they were given a storyline to decode. As seen in Figure 6.1, Lessons 2 and 4 focused mainly on developing the learners' ability to communicate both verbally, as well as in writing. This was seen as the learners explained different sequences to their friends only using drawn arrows. The learners' communication skills proved to have developed significantly after the lessons took place. When looking at the scores from the interviews that were held with the learners' homeroom teachers, six of the seven participants improved, ranging from the improvement of one to four scores, while the seventh participant's score remained the same. This indicates that most of the participants' communication skills did improve, further supporting the key factors that are believed to support the development of 21st century skills. This further relates to the 21st century skill of collaboration.

Collaboration is defined as more than just teamwork, but also the ability to develop good listening skills and to ask questions (Alber, 2012). This is supported in the findings as seen in Figure 6.1, the key factors that aided in developing the skill of collaboration were the implementation of **group work** and the use of constructive **discussions**. Collaboration was developed naturally in the coding and robotics lessons as the children were encouraged to explore and discover each task in groups. The children thus relied on one another when addressing the different tasks. The main development of skills and understanding in these activities was established while the learners completed the tasks alongside their classmates. In order for the tasks to be successful, the learners had to be able to listen and cooperate with one another effectively. Once again, the results from the interviews support the belief that the skill of collaboration developed considerably after the

lessons were presented as six of the seven participants showed improvement, while the seventh participant retained the same level of skill.

The skill of critical thinking is supported in coding and robotics with very little intervention needed. Critical thinking is defined as the ability to think systematically and with sound reasoning (Fadel, 2009). The findings of the study support the literature as many of the lessons were planned with a **trial and error** approach, resulting in the learners having to think for themselves and as a team, not only relying on the teacher to supply answers. As illustrated in Figure 6.1 above, the implementation of the trial and error approach played a role in the development of critical thinking in these lessons as four of the five lessons were designed with that purpose in mind, thus the learners were encouraged to think systematically and with sounds reasoning. Another key aspect that contributed to the development of critical thinking, and which impacted all five lessons, was the planning of activities that require learners to **design and construct.** The learners were encouraged to think as problem solvers when completing tasks. The ability to design and construct presented the learners with opportunities to reason using their own understanding, as well as building on their classmates' understanding. The learners were encouraged to consider different scenarios when constructing a solution, whether it was a sequence around a game reserve grid or guiding a friend to retrieve hidden treasure. This is supported by the interviews held with their teachers as five of the seven participants had improved in their critical thinking. The other two participants remained the same, which was relatively high to begin with. The learners were encouraged to think methodically and to justify each action chosen, whether it related to arrows on a grid or the coding of the robot.

The final 21st century thinking skill to be analysed is the skill of creativity. Creativity is defined as not merely the act of being artistic, but as a range of skills like scientific thinking and mathematical thinking (Bialik & Fadel, 2015). As depicted in Figure 6.1 above, the findings of this study support literature as the children had to think for themselves as they designed and constructed different sequences, grids, code, and objects in the lessons. The key factor of '**design and construct'** had an influence in all five of the lessons as it promoted the skill of creativity. The activities in this study encouraged the learners to think for themselves and to think uniquely yet justifiably. The role of the teacher as a **facilitator** had an impact on the development

of creativity as the learners had to construct their own understanding and had to think for themselves. The interviews highlighted that five of the seven participants improved in their creativity due to their involvement in the coding and robotics lessons. Once again, the other two participants remained the same with a fairly high score of three out of five. The activities were planned with the intention that the learner would explore and evaluate different scenarios to think for themselves and take charge of their own learning and creativity.

6.2.2 SRQ2 How can coding and robotics principles be developed in early childhood education?

While investigating the coding and robotic lessons that occurred, certain principles were addressed when implementing the different lessons. This discussion investigates and combines these principles with the literature from numerous studies in relation to the findings of this study. Figure 6.2 below depicts the different key aspects that were investigated in the lessons, as well as how frequently they occurred throughout the different lessons. The key aspects that were found are further divided into the themes that were investigated in Chapter 5. The themes will be italicised and underlined, while the key aspects will be in bold. The use of the different font styles will allow the reader to identify the themes and key aspects of the findings with ease. The key aspects are linked to the different themes through the use of the three colours in Figure 6.2 below. This allows the reader to clearly see which key aspect relates to which theme, as well as creating connections between various chapters and discussions.

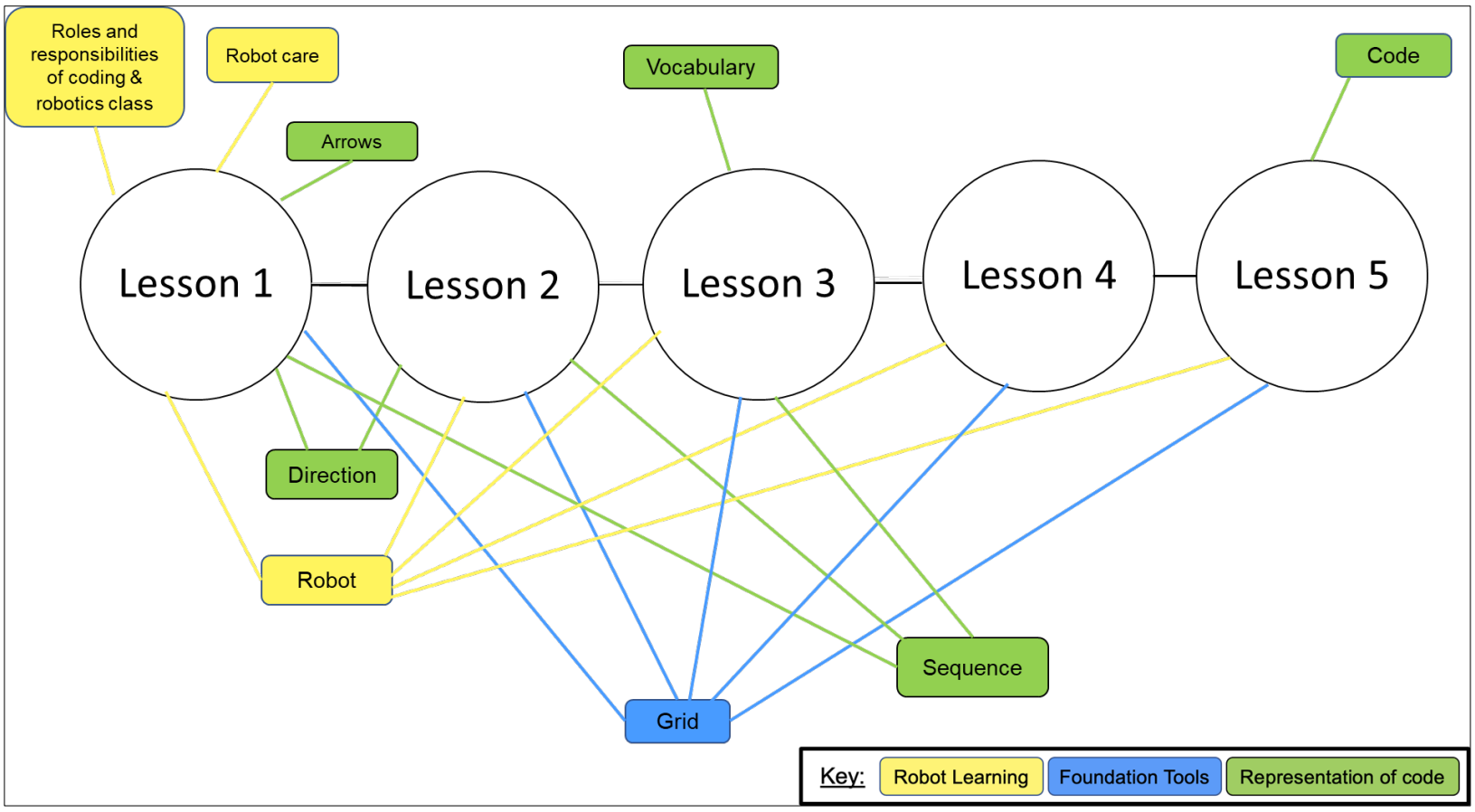


Figure 6-2: A cluster diagram representing coding and robotic principles that were developed during the planned lessons

This study focused on multiple coding and robotics activities that were presented to early childhood learners. The principles of coding and robotics in these planned activities increased in complexity and difficulty as the learners explored further in each activity. Bers (2018) defines coding for early childhood learners as an expressive medium that involves emotional and social domains, alongside cognitive activity. The findings of this study agree with the idea that coding and robotics activities are more than just a cognitive activity, but rather a holistic activity that incorporates different elements of the child's learning, as the learners engaged in multiple activities using multiple thinking skills, reasoning, gross-motor skills and fine-motor skills. The principles of coding and robotics that were implemented in the activities were: the child's ability to care for the robots; a basic understanding of what the robot can do; directionality; grids; and sequences. As seen in Figure 6.2 above, in Lesson 1, the learners discussed the **care of robots**, and actively reminded each other throughout the study to care for the robots. This correlates to the theme of *robot learning*. The learners' basic understanding of what the **robot** can do increased in complexity as the lessons continued. The key aspect of the 'robot', as seen in Figure 6.2, was an element of each lesson. The learners started with a basic understanding of moving forwards and then backwards, which then escalated to the ability to turn the robot around, and then later to solving tasks

through trial and error with the robot. Researchers consider the use of robotics in early childhood education to support the development of problem solving and spatial orientation, as well as a few other skills (Rogers & Portsmore, 2004). The literature and findings from this study are aligned when addressing the development of problem solving and spatial orientation while the learners used the robots in activities. The learners grew in confidence when using the robot and manipulating the robot around and then later spatially around a grid.

Another key aspect, which links to the concept of spatial orientation, was **direction**. In this study, the concept of directionality was encouraged and implemented in the first and second lessons. The children were encouraged to use the correct terminology for direction from the beginning. While guiding one another in the activities, the learners motivated and supported each other, while also reminding each other about their lefts and right side. As illustrated in Figure 6.2 above, the key aspect of **grids** was implemented in every lesson, while **sequences** were implemented in Lessons 1, 2 and 3. These key aspects were connected to the two themes of *representation of code* and *foundation tools.* These themes linked to the learners' ability to adapt their knowledge regarding direction and robots to complex scenarios or environments. The learners were first given a simpler example of a grid and sequence, and were then provided with an explanation, which led to more complex sequences and grids that the learners were encouraged to follow. Once the concepts relating to sequences and grids were grasped, the learners were then encouraged to start constructing their own grids and sequences. Jung and Won (2018) define robotics as an understanding of technological and mechanical knowledge while adapting to complex environments and situations. This notion is supported by the findings of this study as throughout the planned activities the learners were encouraged to implement the skills and knowledge they had learnt regarding coding and robotics into various scenarios and themes. They further had to do this while manipulating themselves and the robots around multiple grids, following and creating different sequences in relation to the grids.

6.2.3 SRQ3 How can coding and robotic activities be setup to best support development in early childhood education?

The reflections that relate to this question supported the development of 21st century skills, and were supported by the findings from the interviews held with the learners' homeroom teachers. The interviews highlighted a significant development, or at least consistency in these 21st century thinking skills in the learners once the lessons had been implemented. Thus, it can be said that the activities in the lesson were successfully implemented. The key aspects discovered in this study are detailed in the cluster diagram below, where the different lessons are clearly marked. The key aspects displayed above relate directly to the discoveries made in each particular lesson. However, the key aspects presented below link to more than one lesson. Those that occurred more than once will also be further discussed.

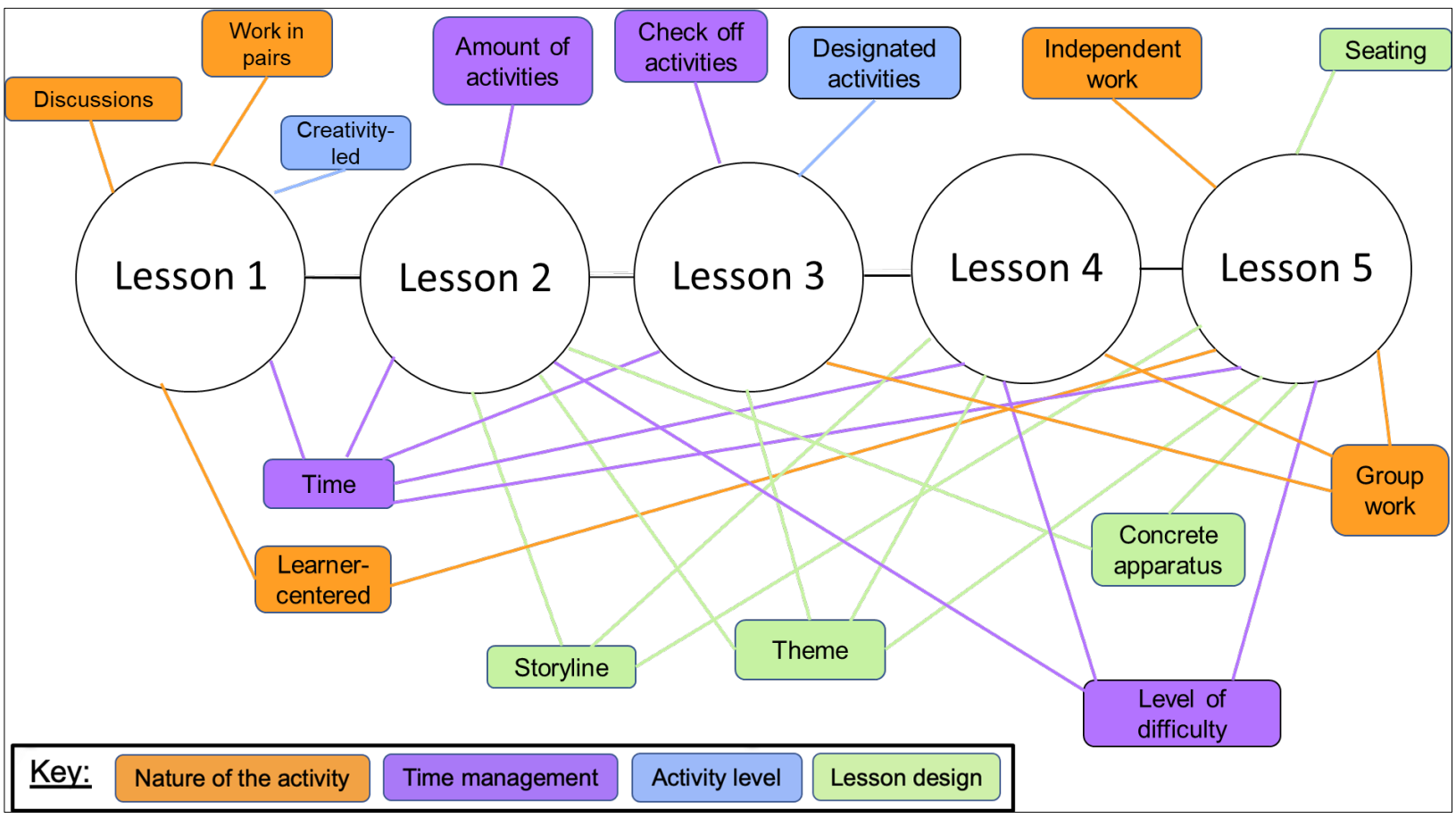


Figure 6-3: The key aspects discovered in the coding and robotics activities

As presented in the diagram above, the various key aspects that are relevant to a specific theme are displayed in the same colour. This allows the reader to easily identify the connections between the different key aspects and the relevant themes. There are a significant number of themes that occurred in more than one lesson, which were: time, learner-centredness, the use of a storyline or theme, the level of difficulty, the use of concrete apparatus, and group work. These themes will be

discussed in the points below with relevant connections to the literature. The key aspects will be in bold and divided into appropriate paragraphs relating to the relevant theme.

6.2.3.1 Lesson design

<u>The implementation of a **theme** and/or **storyline** in the lesson helps to provide young learners with playful learning experiences</u>

Bers et al. (2002) highlight the importance of encouraging young learners to develop active enquiry while participating in playful experiences. This study agrees with the research from Bers (2002) as in the planning of the lessons every activity planned for opportunities for play and exploration. In order for the lessons to be interactive and engaging, the activities were planned to correspond to a particular theme or storyline. These did not need to change for each lesson, but could be used consecutively for a few lessons. The learners showed great enjoyment working according to a theme or storyline, and it allowed the different activities to be placed in context. It further encouraged the children to use their imagination. As illustrated in Figure 6.3 above, the implementation of a theme occurred in four of the five lessons, and the use of a storyline transpired in three of the five. This resulted in the majority of the lessons having some sense of context for the learners. All of the activities in this study aimed to be learner-centered, and emphasised the importance of young learners developing their own understanding through active learning. This was easily achieved with the implementation of a theme or story. Overall the implementation of the theme agrees with the research of Bers (2002) as it provides a playful experience that encourages active enquiry.

<u>The findings of this study encourage the use of a variety of **apparatus**</u>

In this study, the learners were exposed to a variety of activities that were each unique in their outcomes and resources. This is supported in the literature as researchers believe that using different tools supports the development of skills, and increases learners' motivation (Koç & Boyuk, 2013). As depicted in Figure 6.3 above, the use of concrete apparatus was mainly highlighted in the second and the fifth lesson. It is important to present learners with concrete experiences that support the learners' own development of their understanding (Edwards & Springate, 1995). This study agrees with researchers Edwards and Springate (1995) as the lessons

consisted of a variety of activities in each lesson that provided the learners with various different concrete experiences, whether the learners were using their bodies to manipulate around a grid taped on the floor, using a robot, or using pieces of papers placed in a grid like fashion and following drawn arrows. This does not necessarily imply that expensive resources must be used, as the lessons in this study involved tape used as a grid on the floor, Lego, plastic animal figurines, and picture cards. Therefore, a variety of concrete apparatus can be used when implementing lessons.

6.2.3.2 Nature of the activity

Provide a variety of **group** arrangements

The study focused on allowing the learners to work independently and think for themselves in a few activities. It is important to construct activities that encourage the development of communication and collaboration skills, even during the reflection process. The activities that encouraged group work allowed the children to build on each other's understanding, and engage with one another in a fun and competitive was. Kanbul and Uzunboylu (2017) find that teaching robotics to young learners helps develop their fine motor skills and hand-eye coordination, while simultaneously engaging them in collaboration and teamwork scenarios. The study agrees with researchers Kanbul and Uzunboylu (2017) as seen in Figure 6.3, Lessons 3, 4 and 5 all focused on group work, therefore engaging the learners in teamwork scenarios. In all of the lessons, the learners were divided into groups, while the last three lessons focused on how group work can be used to effectively encourage learners to engage with one another. This is an important skill that should be developed from a young age as one of the most sought-after attributes in the workforce is an individual's ability to share solutions and ideas (Gerald, 2015). In this study, the changing of the groups allowed the children to develop their communication and collaboration skills with different individuals as they shared opinions and ideas while considering each activity, which supports researcher Gerald's (2015) findings.

The importance of adopting a **learner-centred approach**

Olusegun (2015) explains that it is important for young learners to have an active role in the acquisition of their own knowledge. This means that activities should be

learner-centred with learners developing their own understanding. It was found in this study that using very little teacher intervention, with the teacher mainly being a facilitator, supports the learners' ability to think critically and creatively. This study aligns with Olusegun (2015) as seen in Figure 6.3, Lessons 1 and 5 addressed the reflection of having a learner-centred approach to the activities, thus allowing the learners to have an active role in their own knowledge construction. This study provided learners with activities that encourage authentic learning, and actively exploring and making sense of their own understanding, empowers young learners.

6.2.3.3 Time management

Time management is important when planning activities

As portrayed in Figure 6.3 above, the reflections regarding time were addressed in every lesson. In general, the findings suggest that sufficient time must be planned for learners to engage in each activity to the fullest extent without being rushed to complete the activity. This study also highlights the importance of planning fewer activities and allowing time for the children to explore the different resources used in each activity. This is supported by research as Perkins (2006) believes that allowing learners to be actively engaged in their own learning leads to better retention and understanding thereof. Therefore, it is important to plan lessons that actively engage learners. Moreover, the difficulty of activities should align with the time spent at each activity so that the learners move between the activities, engaging fully in each lesson.

6.3 MAIN RESEARCH QUESTION DISCUSSION

In this study, each research sub-question linked to the TPACK framework implemented. The data obtained in answering the sub-questions contributed to a collective understanding of the main question under investigation. Figure 6.4 illustrates the key aspects that were discovered in the investigation of each research sub-question separately, as well as the relationship between the questions, and how this collectively answered the main research question. The key aspects and sub-questions are displayed in the appropriate circles. The data from the investigation of these sub-questions provided useful information on how coding and robotics can support the development of 21st century skills in early childhood education.

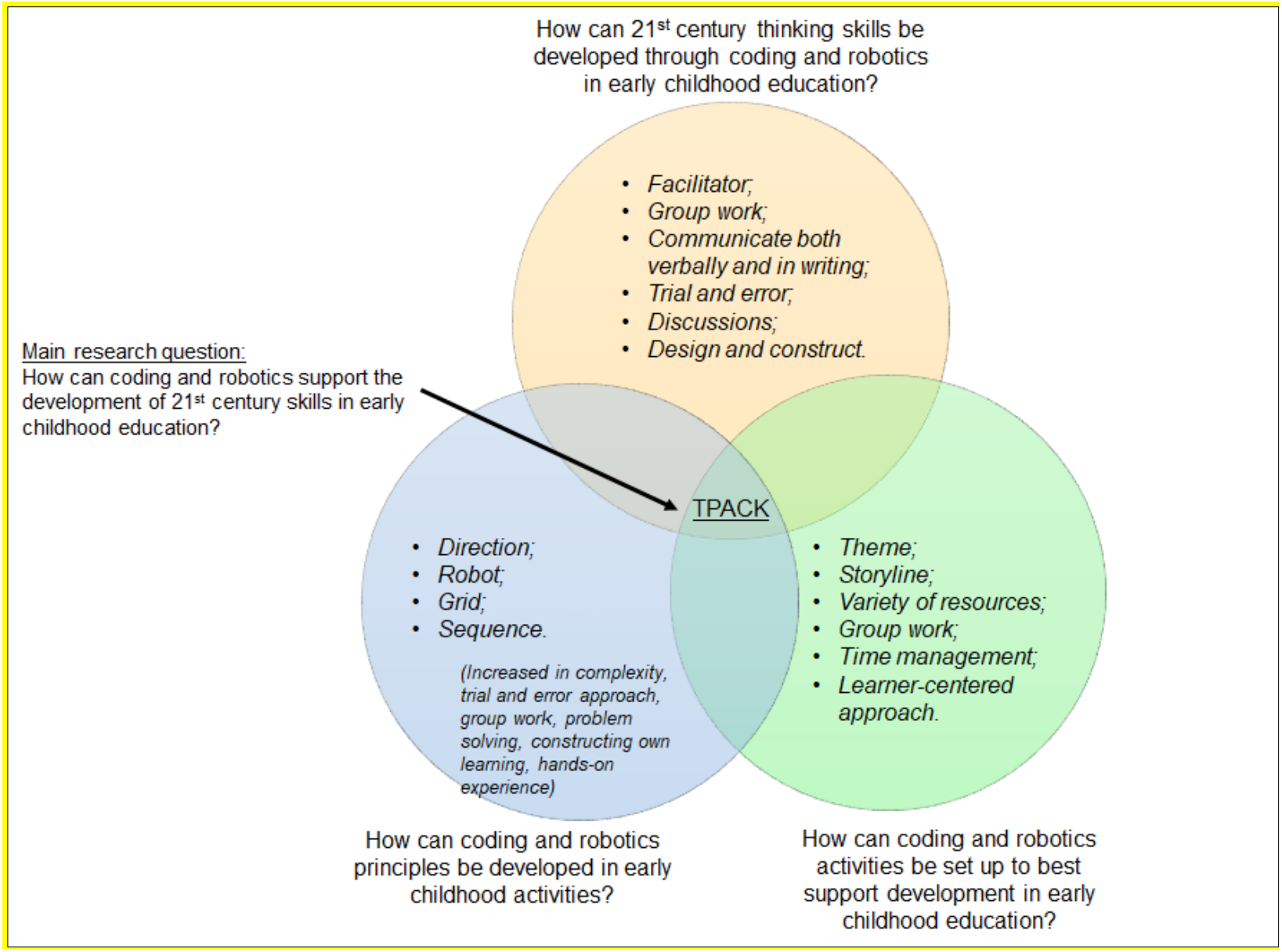


Figure 6-4: TPACK framework showing the key aspects investigated in the separate research sub-questions, as well as how they collectively answered the main research question of this study

The principles that were developed in the coding and robotics lessons, which are portrayed in the blue portion of Figure 6.4, focused on: the learners' development of directionality; the learners' understanding of robots and how to manipulate them; the concept of a grid; as well as the understanding of a sequence and how to construct their own sequences. The manner in which these principles were developed aided in the development of the 21st century skills displayed in the yellow portion of Figure 6.4. The green portion of Figure 6.4 above highlights the key aspects that were implemented in the lessons relating to the development of learning and understanding in early childhood education. This discussion will address how the key aspects found to impact the development of 21st century skills correlated with the key aspects found in the other two portions of this study. Furthermore, specific guidelines will be suggested to assist future teachers when planning early childhood coding and robotics lessons that support the development of 21st century skills.

The first key aspect that impacted the development of 21st century skills in this study's coding and robotics lessons was the role of the teacher as a **facilitator**. In relation to early childhood education, conducting lessons with a **learner-centred approach** relates well to the role of the teacher as a facilitator as both approaches result in the learners constructing their own understanding. These approaches supported the learners' acquisition of understanding regarding how to manipulate a **robot**. The learners were not instructed step by step by the teacher regarding how to manipulate the robot. Instead, they were given tasks that focused on them constructing their own understanding and building on that of their classmates. These planned tasks increased in complexity as the learners started gaining a deeper understanding of how a robot moves and how to manipulate it. The learner-centred approach correlates with the learning approach of **trial and error.** This approach encouraged the learners to plan, evaluate and reflect with each activity presented, and helped them learn how to manipulate the robot. The learners had to constantly re-evaluate and alter the sequence they had planned in order for the robot to reach a specific object placed in front of them. The learners used problem solving through trial and error to eventually succeed in the activity. The findings show that incorporating these approaches in the lessons helped develop the participating learners' thinking skills. The learners' ability to think critically and creatively was focused on as they engaged in different activities that required them to solve problems for themselves and think of unique ways to complete the activity. Their ability to communicate and collaborate was also seen to improve throughout the lessons as they had to express their thinking to their classmates and the teacher.

The learners were also placed in **groups**. As depicted in Figure 6.4 above, both the yellow and green portions highlight the use of **group work.** The learners were required to work together in each activity, which resulted in the learners solving problems and supporting the development of each other's learning. The majority of the lessons planned incorporated group work. As such, the learners had to consider and evaluate one another ideas and opinions, and implemented this thinking when guiding each other on a **grid.** The learners were required to guide a classmate who was blindfolded along a grid while considering the quickest and 'safest' sequence. The learners engaged in thoughtful **discussions** as they took part in each activity, resulting in exciting new discoveries and supporting the construction of each other's

understanding. The implementation of group work supported the learners' communication and collaboration skills as they had to effectively express their thinking and justify their opinions either **verbally or in writing**. The learners were also required to consider other learners' opinions and help one another to solve problems as a team. This relates to critical thinking as the learners were unintentionally evaluating and justifying their own thinking and that of their classmates.

As illustrated in Figure 6.4 above, the last key aspect in the yellow portion is the learners' ability to **design and construct**. This relates to the manner in which the lessons were planned. When looking at the green portion of the figure above, the incorporation of a **theme**, **storyline** and a **variety of resources** aided in providing the learners with opportunities to design and create solutions that fit a specific context, which fully engaged them in the lesson. When the learners were completing activities that focused on **sequences** or **direction**, they were required to construct their own sequence while considering multiple factors that related to the story or theme. When planning the activities, it was important to **manage the time** effectively. The learners need sufficient time to plan and construct without feeling rushed. The learners were provided multiple resources to help them design and construct (e.g. Lego, sequence strips, beads, and so on). This gave learners opportunities to develop their creativity and critical thinking skills as they planned and designed different sequences or objects within a specific context. The learners were also encouraged to explain their creations and the thinking behind their designs, which is believed to aid in the development of learners' communication skills.

This discussion focused on investigating the relationship between the different aspects found. These key aspects were used to develop a list of relevant guidelines for teachers. Based on the findings of this study, it can be said that incorporating these guidelines when planning coding and robotics activities for early childhood learners could support the development of 21st century thinking skills.

6.4 GUIDELINES

The guidelines developed in this study aim to assist future teachers when planning early childhood coding and robotics lessons that support the development of 21st century skills. These guidelines can be traced back to the tables presented in Chapter 4 regarding the planned activities. These were then collated in Chapter 5 as key aspects, and finally, the guidelines were abstracted in Chapter 6 through the discussions and cluster diagrams presented in the chapter. The suggested guidelines are as follows:

- Plan lessons where the teacher is only a facilitator.
- Incorporate learner-centred activities.
- Plan lessons with various group work activities.
- Create opportunities for learners to communicate both verbally and in writing.
- Implement a trial and error approach in activities.
- Plan lessons in accordance with a theme or storyline.
- Use a variety of resources in the lessons (these do not necessarily need to be costly).
- Encourage opportunities for the learners to discuss their findings and understanding.
- Plan activities that encourage the learners to design and create.

Manage the time spent on each activity wisely to ensure that the learners have enough time to explore each task fully.

6.5 CONTRIBUTIONS

The present study attempts to answer the question of how coding and robotics can support the development of 21st century skills in early childhood education, and in doing so makes some important practical contributions. These contributions aim to assist teachers who engage with coding and robotic activities with their learners.

The first contribution is the greater understanding of designing activities that incorporate the development of the four 21st century thinking skills. As illustrated in

Figure 6.1 above, there are key aspects that were discovered that highlights ways that the planning and design of an activity can aid in the development of 21st century thinking skills; communication, collaboration, critical thinking and creativity. The findings contribute to a teachers practically, as it encourages teachers to apply their knowledge of the different 21st century thinking skills while planning and designing their lessons. The second contribution is the understanding that coding and robotic lessons can be designed without sizable funds or internet access. Some of the activities that were planned in this study used plastic toys that were available in the classroom, or paper and pencils. However, the foundational thinking of the coding and robotic principles was still applied. As seen in figure 6.2, the incorporation of a grid, whether printed or taped on the floor, was implemented in all of the presented lessons as well as the representation of code, whether drawn arrows or rearranged printed arrows, was used to present code instead of a technological device or the use of the internet. The third contribution focuses on the design and planning of a coding and robotic lesson, which allows the lesson to be learned-centred. In the Figure 6.3 it shows multiple key aspects that played a role in the lessons provided to the learners. These key aspects can assist teachers when designing and planning their own lessons, that allows the teacher to merely facilitate whilst the lesson takes place and allows the learners to work together and apply their own understanding to the different activities. It is important to effectively plan and design the lessons, as the manner in which the lesson is designed impacts the learners engagement.

6.6 Reflections

6.6.1 Personal Reflection

In this section, the researcher will reflect on the journey she underwent while conducting this study. This section will be divided into the different phases that were encountered as the study developed up until its completion.

When choosing the research topic, the researcher was immediately drawn to the concept of coding and robotics. She had heard of some schools embracing this new trend in education, and could see the relevance it has in the world today. However, as the researcher delved deeper into the literature review, she developed a desire

to prepare young learners for a progressively modernised world (Pudiyono, 2019). As a teacher herself, she began to think of ways in which she could prepare every learner that entered her class, but realised that there was no template that she could follow to ensure that the planned lessons were actually beneficial. Therefore, this research aimed to create a set of guidelines for other teachers to follow while planning different lessons that specifically promote 21st century skills. Previous literature in this field reveals that it is fundamental to start incorporating 21st century skills into lessons for young learners. Furthermore, this equips learners with knowledge that they will need to be more competitive in current society (Ahmed & Gut, 2020). The researcher started to see a relationship forming between the benefits of coding and robotics and those of incorporating 21st century thinking skills into early childhood learners' classes.

While planning the activities, the researcher focused on preparing fun and interactive activities, similar to those she would typically plan for her homeroom class, but instead with a coding and robotics framework. When implementing the lessons and observing the learners as they interacted in the lessons, it was incredible to see the interest it caused in their young minds. It was obvious that the learners were motivated by the subject of coding and robotics. It was fascinating to observe the participating learners as they not only engaged with the different resources, but started constructing and designing their own understanding as they thought of new ways to manipulate the robot or design a new sequence. This is supported by research as it is believed that coding encourages young learners to produce and not merely consume technology (Bers, 2018). The researcher worked alongside another teacher who assisted with the observation of the lessons. The discussions they had as the lessons transpired motivated and excited them when planning the next activity. The researcher and her fellow teacher noticed how the learners eagerly engaged in the lessons, and the benefits thereof could be seen in terms of the 21st century skills. However, it was not until she interviewed the learners' homeroom teachers that she understood the full impact that the lessons had on the learners. The teachers were exceedingly helpful in providing information and were just as amazed as the researcher when noticing the development that each child had shown in the different 21st century skills. The research process was shared with the parents of the children as well. A booklet was created, which is

available in Appendix G. This booklet shares the activities that took place, as well as some feedback for the parents. This aided in engaging in many insightful discussions with the parents. Many parents noted how excited their children were to attend the coding and robotics lessons, as well as the difference they noticed in their children it terms of their thinking, such as the types of questions the children had begun to ask.

6.6.2 Critical viewer reflection

While reflecting on this study, it was deemed beneficial to consult the teacher who was involved in the implementation of the lessons, and who was a keen observer of the young learners' development. The findings were shared with her and she was asked for her opinion, considering the discovered guidelines, as well as any key discoveries she observed during the lessons. This teacher therefore took on the role of a critical reviewer. Discussing the developed guidelines with the critical reviewer was a constructive process.

One of the guidelines specifically focused on implementing themes or a story in the lessons. This provided the learners with various opportunities to design and create within a context that was relevant to, and engaging for the learners. The critical reviewer agreed with this, stating,

> *The researcher developed lessons and themes and we soon found out how the children responded positively to a common theme that was used during the whole term. This made it more relatable, and the young learners were able to continuously build on the knowledge that they gained from the previous sessions.*

The implementation of a theme or storyline relates well to the constructivist teaching philosophy as learners are encouraged to engage with their learning, and work on their ability to manipulate tools. In constructivism, learners should play an active role in their own learning, which should include fun and playful experiences (Bers et al., 2002). The critical reviewer and the researcher also discussed the implementation of different stations. They planned for various stations at which the learners would alternate roles, and each station presented a different activity. The critical reviewer further explained,

> *We also discovered that creating different stations worked well within the lessons. The young learners were able to move from one station to the next creating structure within the class and allowing each learner to grow and develop different skills that were targeted during the activities.*

This once again links to the constructivist learning philosophy and encourages the teacher to have a facilitator role during the lesson. The learning was centred around the learners and their peers. This is highlighted in the guideline of teamwork, where the learners are encouraged to work together. The critical viewer said that,

> *During my observation, it was wonderful to note the teamwork amongst the children. When the learners were placed into groups, they had the ability to share their ideas and build on one another's concepts, therefore supporting 21st century thinking. The learners developed their communication and language skills as well. The learners had to effectively and clearly explain to their peers how to complete an activity. It was observed during the initial sessions this was a difficult task for some learners, and by the end of the sessions the learners had the ability to explain and understand instructions given to them by their fellow peers.*

The researcher and critical reviewer also discussed the importance of the skill of group work in the development of communication and collaboration. In order for the learners to successful complete each activity, they needed to work together and communicate effectively. Researchers report that effective collaboration skills are defined as the ability to work with diverse people in groups and to cooperate with others (Kift et al., 2010).

When discussing the type of activities that were presented, the critical reviewer and the researcher noticed that there were a variety of hands-on activities planned. They discussed how they had both noticed that the learners engaged well with activities that encouraged a hands-on experience. This is supported in the literature, as Reggio Emilia researchers believe that concrete learning environments should focus on stimulating the learners' social, cognitive, and linguistic skills (Rinaldi 2003). The critical reviewer mentioned in the discussion,

> *The lessons that were prepared created opportunity for the learners to have a hands-on experience, as well as a written paper activity. We identified this strategy to be effective as the learners learned how to apply their learning in different contexts and*

> *situations. Their learning was never isolated to one activity but rather several activities that grew their understanding of coding and robotics.*

Thereafter, the designed activities were discussed, which provided the learners with unique concrete environments. However, it was realised that the activities were not centred around expensive items of technology. The critical reviewer made a note that,

> *It was interesting to note that sessions didn't always include expensive resources. It was observed that resources like different coloured blocks and paper created a coding learning experience for young learners.*

It became apparent that the design of the variety of concrete activities was beneficial to the holistic development of the learners. This was evident in the change that gradually occurred in the different learners. The critical reviewer added,

> *Throughout my observation, it was wonderful to note that the learners grew in holistically. Making the sessions learner-centred allowed them to explore the world around them as well as lead their own learning. The learners often surprised us in their problem-solving skills and creativity.*

This once again relates to the literature as researchers find that incorporating coding and robotics at a young age can assist in the development of multiple cognitive and social milestones and skills (Sullivan & Bers, 2015). When discussing the 21st century skills that were developed with the critical viewer, she made the discovery that although the primary focus of the lessons was the learners' critical thinking skills, which was promoted by creating problems for them to solve, the learners actually started to develop a positive mindset regarding solving problems in general. When discussing this, it was discovered that not only were the learners' problem-solving skills being developed, but their opinion and attitude had begun to change as well. The learners no longer felt overwhelmed when trying to solve problems without the assistance of the teacher. This was deemed to be a beneficial attribute that would support these learners in the future.

The discussion with the critical reviewer provided a different framework to another teacher who was involved in the presentation of the lessons. The critical reviewer expanded and highlighted certain discoveries that occurred in the presentation of, and reflection on the different lessons.

6.7 LIMITATIONS

This study had potential limitations that could affect the final results. The lack of prior research regarding this phenomenon is considered a limitation. The lack of literature caused difficulty in constructing the study's research objectives. However, there is significant research on the separate factors analysed in this study, such as 21st century thinking skills; coding and robotics; and early childhood education. The lack of accessible information regarding designed coding and robotics lessons that are suitable for young learners was a limitation in this study. The researcher planned lessons based on the research. However, the draft coding and robotics curriculum that was released after the lessons were presented would have provided the researcher with a better framework to present the different lessons. Therefore, if the study were to be redone or replicated, it would be beneficial to do so in accordance with the drafted South African coding and robotics curriculum. Another limitation in this study was the sample size. The sample size of this study was seven participants who were enrolled at a particularly affluent school. This led to a limitation in the study as the small class size meant that the results may not be generalisable, and may be difficult to replicate in other coding and robotics class scenarios. Moreover, incorporating a larger sample size may aid in gaining more accurate results. The study occurred over the course of a few weeks, consisting of five lessons. The duration of the lessons was thirty minutes long. The study captured a fair amount of data, and the teachers involved in the interviews noticed a change in the learners over the five lessons. Nonetheless, the researcher believes that it will be beneficial for the study to be extended as this may provide more detailed results. Lastly, the researcher took on many roles in this study. This was difficult to manage as the researcher was simultaneously the facilitator, planner, and observer in the lessons. If the study were to be replicated, I would recommend that the researcher takes on the role of the observer, and allows another teacher to be the facilitator and planner of the lessons. The study was implemented in an affluent school in South Africa, however many South African schools have the battle of affordability to consider when planning and implementing coding and robotic activities. Although the researcher addressed this issue when planning and implementing activities, that contained a combination of activities with both the costly resources and other activities with more easily accessible resources, I would recommend that future

studies provide more of a South African context when designing activities, with few financial barriers.

6.8 RECOMMENDATIONS

This section presents the recommendations for future research. The study developed a set of guidelines that will assist teachers in planning coding and robotics activities for early childhood learners that best support the development of 21st century thinking skills. It is recommended that these guidelines be investigated further and implemented in future studies. Such studies should also focus on investigating the impact that 21st century thinking skills has on the preparation of young learners for a technology driven world.

When discussing the 21st century thinking skills in the interviews with the homeroom teachers, it was noted that the teachers were not confident in their understanding of these specific skills. It is thus important for teachers to have a clear understanding of what 21st century skills entail. Therefore, appropriate training in 21st century skills is recommended for teachers.

Moreover, the critical reviewer involved in this study has a background in speech therapy. As such, she highlighted how the coding and robotics activities supported the development of 21st century skills related to speech therapy. She specifically noted that building these skills in learners could support therapists in activities that target auditory processing and other speech and language difficulties. Therefore, the researcher recommends further studies that investigate the connection between 21st century skills, coding and robotics, and therapy for speech and language difficulties.

6.9 BENEFITS TO THE FIELD OF STUDY

This study aimed to develop specific guidelines that teachers can implement when designing activities in coding and robotics that best support the development of 21st century skills for early childhood learners. These guidelines are believed to contribute to the field of education, particularly in a South African context. This study provides teachers with practical guidelines that will ultimately aid in best equipping early childhood learners with vital skills for the future. This research provides

teachers with a better understanding of the relationships between coding and robotics, and 21st century thinking skills. It also provides readers with detailed information regarding different coding and robotics activities that can be used in early childhood education.

6.10 FINAL CONCLUSION

The purpose of this study was to develop guidelines to help teachers design activities in coding and robotics that support the development of 21st century skills in early childhood learners. While developing these guidelines, this study developed a deeper understanding of the different concepts and how the development of 21st century skills occur during coding and robotics activities. Simultaneously, it was discovered that the resources required for such activities do not need to be costly, and can, in fact, be quite inexpensive. This therefore extends the use of these guidelines to schools that do not necessarily have the finances to source such tools/equipment.

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APPENDICES

APPENDIX A - INTERVIEW SCHEDULE

Interview Schedule:

Topic: Development of 21st century skills in Early Childhood Learners Through Coding and Robotics

RESEARCH QUESTION: How can coding and robotics support the development of 21st century skills in Early Childhood Education?

1	What does coding and robotics in early childhood education mean to you?
	Interview Notes: _____ _____ _____
2	What do you know about 21st century skills?
	Interview Notes: _____ _____ _____
3	Do you believe the development of 21st century skills to be beneficial?
	Interview Notes: _____ _____ _____
4	Do you believe there are opportunities for learners to communicate within the classroom?
	Interview Notes: _____ _____ _____
5	Do you believe there are opportunities for learners to collaborate in the classroom?
	Interview Notes:

	_____ _____ _____
6	Do you believe there are opportunities for learners to think critically in the classroom?
	Interview Notes: _____ _____ _____
7	Do you believe there are opportunities for learners to be creative in the classroom?
	Interview Notes: _____ _____ _____

Questions related to the individual learner:

Participant 1:		
Circle the number: *(1-poor, 2-fair, 3-average, 4-good, 5-excellent)*		
Content knowledge	Communication	1. 2. 3. 4. 5.
	Collaboration	1. 2. 3. 4. 5.
	Critical thinking	1. 2. 3. 4. 5.
	Creativity	1. 2. 3. 4. 5.
Comments:_____ _____ _____		

Participant 2:		
Circle the number: *(1-poor, 2-fair, 3-average, 4-good, 5-excellent)*		
Content knowledge	Communication	1. 2. 3. 4. 5.
	Collaboration	1. 2. 3. 4. 5.
	Critical thinking	1. 2. 3. 4. 5.
	Creativity	1. 2. 3. 4. 5.

Comments:_____ _____ _____

Participant 3:		
Circle the number: *(1-poor, 2-fair, 3-average, 4-good, 5-excellent)*		
Content knowledge	Communication	1. 2. 3. 4. 5.
	Collaboration	1. 2. 3. 4. 5.
	Critical thinking	1. 2. 3. 4. 5.
	Creativity	1. 2. 3. 4. 5.
Comments:_____ _____ _____		

Participant 4:		
Circle the number: *(1-poor, 2-fair, 3-average, 4-good, 5-excellent)*		
Content knowledge	Communication	1. 2. 3. 4. 5.
	Collaboration	1. 2. 3. 4. 5.
	Critical thinking	1. 2. 3. 4. 5.
	Creativity	1. 2. 3. 4. 5.
Comments:_____ _____ _____		

APPENDIX B - CONSENT FORMS

SCHOOL CONSENT

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education

Dear Principal,

RE: PARTICIPATION IN A RESEARCH PROJECT

I am currently enrolled for a Master's degree at the University of Pretoria. Part of the requirements for the awarding of this degree is the successful completion of a significant research project in the field of education.

The title of my approved research study is **"Development of 21st Century Skills in Early Childhood Learners Through Coding and Robotics"**

The purpose of this study is to develop guidelines to design activities in coding and robotics that support the development of 21st century skills. By developing guidelines for educators to successful plan and present coding and robotic activities, this will better support the development of 21st century skills in early childhood learners, particularly in a South African context. This study will ultimately aid in best equipping early childhood learners with vital
skills for the future.

Your school is hereby invited to participate in this research project, which aims to:

1.4.1 Understand the relationship between coding and robotics to 21st century thinking skills

1.4.2 Determine the benefits of coding for the preparation of young learners in a technology driven world

1.4.3 Gain detailed insight into coding in early childhood education and activities that are currently underway

Below is the scope of the study.

To gather information, I require to approach teachers with an individual invitation to participate. Those who do agree to participate will be interviewed about learners who have participated in particular coding activities. This interview should take no longer than 60 minutes, and can be conducted at any location the participants suggest. The interview, with their permission, will be audiotaped to ensure that accurate information is captured.

The learners will be observed during the coding and robotics extra-curricular lessons. For observation purposes I will be observing the interaction of the learners during the coding and robotics activity and analyse the development of their 21st century skills. Data collection will take place by a photo and video journal and through the evolution of activities. The photos and videos will conceal the faces of the learners in order to keep their identity private.

Please understand that the decision for your school to participate is completely voluntary and that permission for your participation will also be protected by the Independent Education Board. Please also note that each individual's participation in the study will be completely voluntarily and will in no way be a disadvantage to them. Each participant will be free, at any stage during the process, to withdraw their consent to participate, in which case their participation will end immediately without any negative consequences. Any and all data collected from them up to that point in the study will then be destroyed.

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. 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.

At the end of the research study you will be provided with a copy of the research report containing both the findings of the study and recommendations. This research study presents a unique opportunity for your school to get involved in the process of research aimed at investigating the development of 21st century skills in coding and robotics for

early childhood learners. If you decide to allow your school's participation, kindly complete the consent form at the end of this letter.

Thanking you for your consideration in this research study.

Yours in service of education,

Ms E. van der Wal
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UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education

LETTER of CONSENT

SCHOOL AS PARTICIPANT

VOLUNTARY PARTICIPATION IN THE RESEARCH PROJECT ENTITLED

"Development of 21st Century Skills in Early Childhood Learners Through Coding and Robotics"

I, _____ the principal of _____ hereby voluntarily and willingly agree to allow my school to participate in the above-mentioned study introduced and explained to me by Embeth van der Wal, currently a student enrolled for an Master's degree at the University of Pretoria.

I further declare that I understand, as was explained to me by the researcher, the aim, scope, purpose, possible consequences and benefits, and methods of collecting information proposed by the researcher, as well as the means by which the researcher will attempt to ensure the confidentiality and integrity of the information she collects.

_____ _____

Full name Signature

_____

Date

Official Stamp

PARENTAL CONSENT

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education

Dear parent,

RE: PARTICIPATION IN A RESEARCH PROJECT

I am currently enrolled for a Master's degree at the University of Pretoria. Part of the requirements for the awarding of this degree is the successful completion of a significant research project in the field of education.

The title of my approved research study is **"Development of 21st Century Skills in Early Childhood Learners Through Coding and Robotics".**

The purpose of this study is to develop guidelines to design activities in coding and robotics that support the development of 21st century skills. By developing guidelines for educators to successful plan and present coding and robotic activities, this will better support the development of 21st century skills in early childhood learners, particularly in a South African context. This study will ultimately aid in best equipping early childhood learners with vital skills for the future.

Your child is hereby invited to participate in this research project, which aims to:

1.4.1 Understand the relationship between coding and robotics to 21st century thinking skills

1.4.2 Determine the benefits of coding for the preparation of young learners in a technology driven world

1.4.3 Gain detailed insight into coding in early childhood education and activities that are currently underway

Below is the scope of the study.

The learners will be observed during the coding and robotics extra-curricular lessons. For observation purposes I will be observing the interaction of the learners during the coding and robotics activity and analyse the development of their 21st century skills.

Data collection will take place by a photo and video journal and through the evolution of activities. The photos and videos will conceal the faces of the learners in order to keep their identity private.

The child's homeroom teacher will also be asked to participate in the study. The teachers will take part in an interview before and after the coding and robotics activities have occurred. The child's homeroom teacher will also observe whether, the said 21st century skills have developed after the implementation of the planned activities.

Please understand that the decision for your child to participate is completely voluntary and that permission for your child's participation will also be protected by the Independent Education Board. Please also note that each individual's participation in the study will be completely voluntarily and will in no way be a disadvantage to them. Each participant will be free, at any stage during the process, to withdraw their consent to participate, in which case their participation will end immediately without any negative consequences. Any and all data collected from them up to that point in the study will then be destroyed.

We also would like to request your permission to use the studies data, confidentially and anonymously, for further research purposes, as the data sets are the intellectual property of the University of Pretoria. 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.

At the end of the research study you will be provided with a copy of the research report containing both the findings of the study and recommendations. This research study presents a unique opportunity for your child to get involved in the process of research aimed at investigating the development of 21st century skills in coding and robotics for early childhood learners. If you decide to allow your child's participation, kindly complete the consent form at the end of this letter.

Thanking you for your consideration in this research study.

Yours in service of education,

Ms E. van der Wal
Student Researcher

University of Pretoria

ebethvdw@gmail.com

(078)460 2024

Prof Ronel Callaghan
Supervisor

University of Pretoria

ronel.callaghan@up.ac.za

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YUNIBESITHI YA PRETORIA

Faculty of Education

LETTER of CONSENT

PARENTAL CONSENT

VOLUNTARY PARTICIPATION IN THE RESEARCH PROJECT ENTITLED

"Development of 21st Century Skills in Early Childhood Learners Through Coding and Robotics"

I, _____ the parent of

_____hereby voluntarily and willingly agree to allow my child to participate in the above-mentioned study introduced and explained to me by Embeth van der Wal, currently a student enrolled for a Master's degree at the University of Pretoria.

I further declare that I understand, as was explained to me by the researcher, the aim, scope, purpose, possible consequences and benefits, and methods of collecting information proposed by the researcher, as well as the means by which the researcher will attempt to ensure the confidentiality and integrity of the information she collects.

_____ _____

Full name Signature

_____

Date

LEARNER ASSENT

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education

LETTER of ASSENT

CHILD'S ASSENT

VOLUNTARY PARTICIPATION IN THE RESEARCH PROJECT ENTITLED

"Development of 21st Century Skills in Early Childhood Learners Through Coding and Robotics"

Name:_____

I understand that the researcher is interested in watching and taking a photograph of me while at coding and robotics. I understand that the researcher would like to talk to me about what I am doing.

I would like to have my photo taken.		
I would like to talk to the researcher.		

Student researcher: _____

Date

Supervisor: _____

1

TEACHER CONSENT

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education

Dear teacher,

RE: PARTICIPATION IN A RESEARCH PROJECT

I am currently enrolled for a Master's degree at the University of Pretoria. Part of the requirements for the awarding of this degree is the successful completion of a significant research project in the field of education.

The title of my approved research study is **"Development of 21st Century Skills in Early Childhood Learners Through Coding and Robotics"**

The purpose of this study is to develop guidelines to design activities in coding and robotics that support the development of 21st century skills. By developing guidelines for educators to successful plan and present coding and robotic activities, this will better support the development of 21st century skills in early childhood learners, particularly in a South African context. This study will ultimately aid in best equipping early childhood learners with vital skills for the future.

Your school is hereby invited to participate in this research project, which aims to:

1.4.1 Understand the relationship between coding and robotics to 21st century thinking skills

1.4.2 Determine the benefits of coding for the preparation of young learners in a technology driven world

1.4.3 Gain detailed insight into coding in early childhood education and activities that are currently underway

Below is the scope and responsibility of your participation.

To gather information, I am required to approach homeroom teachers with an individual invitation to participate. Those who do agree to participate will be interviewed about learners who have participated in particular coding and robotics

activities that occurred during their extracurricular lesson. This interview should take no longer than 60 minutes, and can be conducted at any location the participants suggest. The interview, with your permission, will be audiotaped to ensure that accurate information is captured.

Please understand that your decision to participate is completely voluntary and that permission for your participation will also be protected by the Independent Education Board. Please also note that each individual's participation in the study will be completely voluntarily and will in no way be a disadvantage to them. You will be free, at any stage during the process, to withdraw your consent to participate, in which case your participation will end immediately without any negative consequences. Any and all data collected from you, up to that point in the study, will then be destroyed.

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. 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.

At the end of the research study you will be provided with a copy of the research report containing both the findings of the study and recommendations. This research study presents a unique opportunity for you to get involved in the process of research aimed at investigating the development of 21st century skills in coding and robotics for early childhood learners. If you decide to participate, kindly complete the consent form at the end of this letter.

Thanking you for your consideration in this research study.

Yours in service of education,

Ms E. van der Wal
Student Researcher

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Faculty of Education

LETTER of CONSENT

TEACHER AS PARTICIPANT

VOLUNTARY PARTICIPATION IN THE RESEARCH PROJECT ENTITLED

"Development of 21st Century Skills in Early Childhood Learners Through Coding and Robotics"

I, _____ the teacher of

_____hereby voluntarily and willingly agree to allow my school to participate in the above-mentioned study introduced and explained to me by Embeth van der Wal, currently a student enrolled for an Master's degree at the University of Pretoria.

I further declare that I understand, as was explained to me by the researcher, the aim, scope, purpose, possible consequences and benefits, and methods of collecting information proposed by the researcher, as well as the means by which the researcher will attempt to ensure the confidentiality and integrity of the information she collects.

_____ _____

Full name Signature

_____

Date

Official Stamp

APPENDIX C – PLANNED LESSON ACTIVITIES

LESSON ONE

<table>
<tr><td colspan="3">Activity 1:</td></tr>
<tr><td rowspan="4">Context</td><td>Topic:</td><td>Introduction to coding & robotics</td></tr>
<tr><td>Total Activity Time:</td><td>30 minutes</td></tr>
<tr><td>Number of learners:</td><td>6 learners</td></tr>
<tr><td>Resources used:</td><td>• floor tiles
• coding critters
• plastic animal figurines
• paper blocks
• grid #1
• pencils</td></tr>
<tr><td>Aims</td><td colspan="2">• understanding the roles and responsibilities of coding and robotics class
• how to care for the robots
• basic understanding of what the robot can do
• direction (forward, backwards, left, right)
• understanding of a grid. One block= one step/action
• understanding that arrows show direction
• how to use a sequence strip
• how to construct own sequences</td></tr>
<tr><td>Plan</td><td colspan="2"><u>Introduction: (5 minutes)</u>
• learners stood on a line that was taped to the floor. The teacher called out direction instructions.
• Instructions started with single instructions (forward, backwards, left, right)
• Instruction then were combined in pairs (e.g. forward, right)
• Instruction were then linked (forward, right, forward, forward, left)

<u>Main: (20 minutes)</u>
There were three different activities. The children were divided into pairs and they moved between the different activities.</td></tr>
</table>

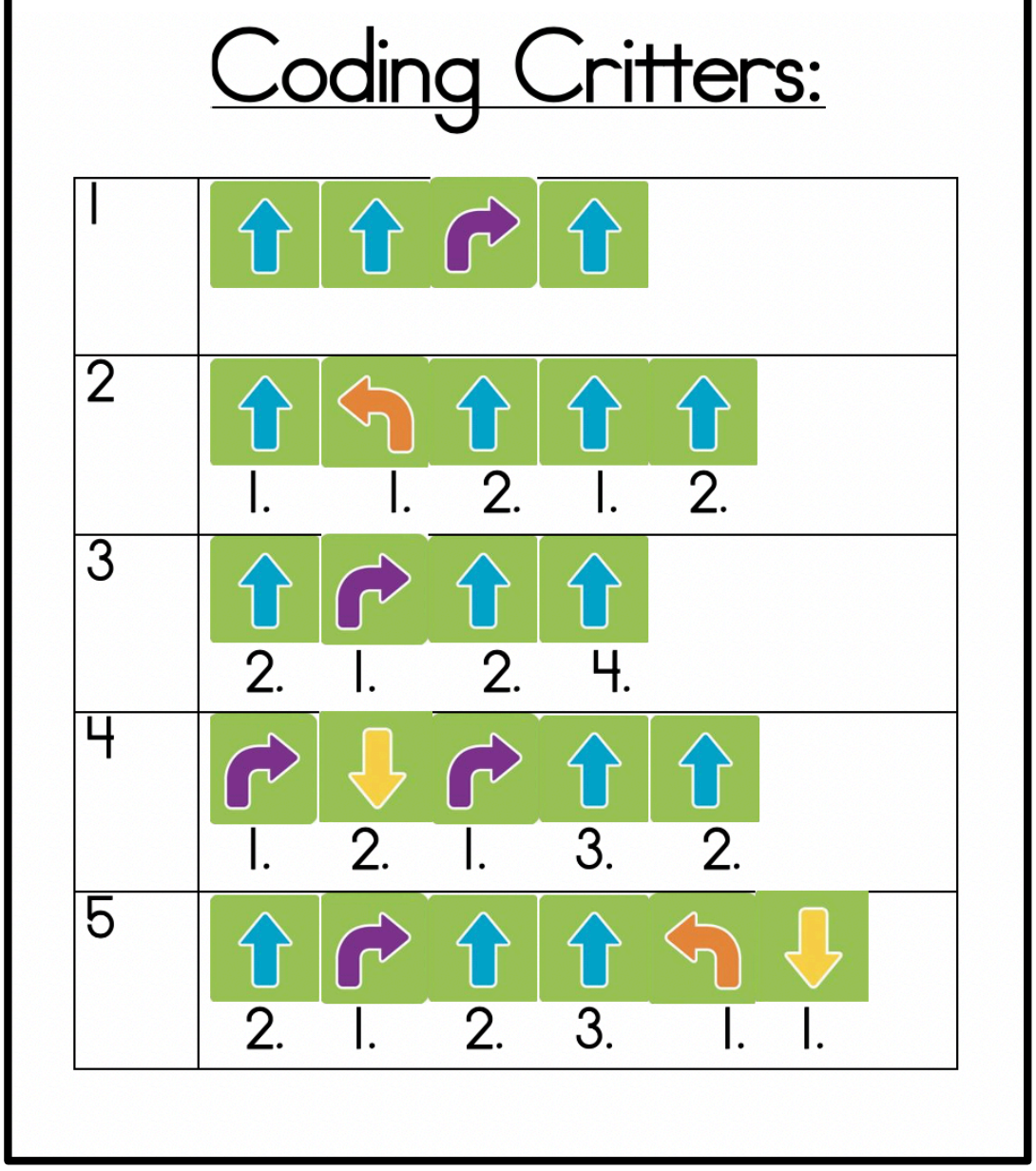
Activity 1:

- *A grid was created with square blocks of white paper.*
- *Plastic animal figurines were placed randomly only the grid.*
- *The children took turns. One child was an instructor and the other was a collector. The instructor would stand and instruct the other child where to move in order to collect the animals as fast as they can. The collector would listen to the instructor and move around the grid with a bucket, collecting the animal figurines.*

(Communication, Critical thinking, Collaboration)

Activity 2:

- *The children continued to work in pairs. They were given a Coding Critters with different sequencing strips that they were required to work through. There was very little instruction from the teacher. The children had to discover how to make the Coding Critters move. The children took turns solving the different sequences.*
- *The children were then encouraged to create their own sequences. One child would use the arrow cards to plan their own sequence and the other child would use the coding critter to act out the planned sequence. The children took turn to alternate roles.*



(Communication, Collaboration, Creativity)

Activity 3:

- *There were floor tiles that were designed for the children to follow. It is a fun activity, similar to hopscotch.*
- *The children were then able to design their own floor tile sequence for their friends to follow.*

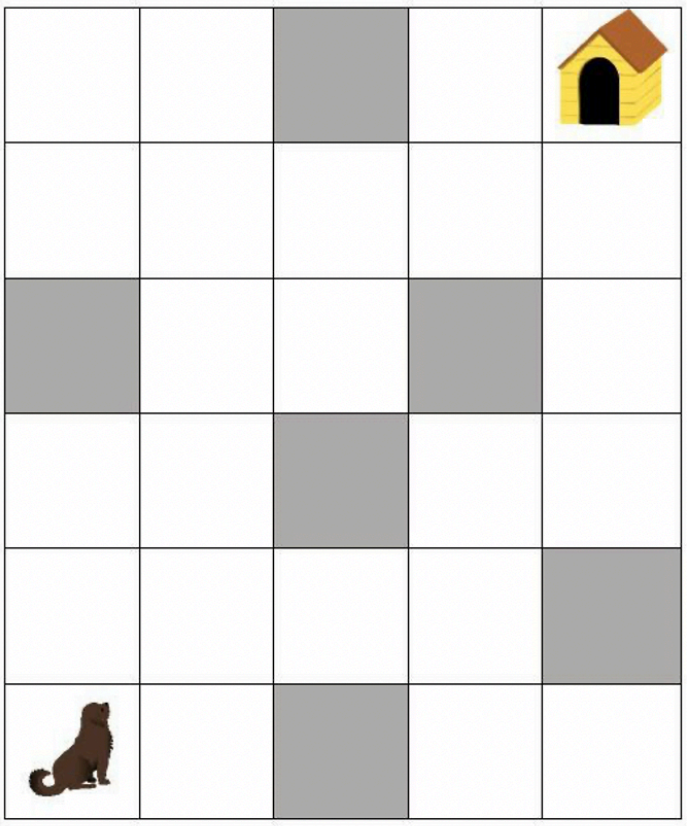
(Critical Thinking, Collaboration)

<u>Conclusion: (5 minutes)</u>

- *The children were given a grid and their own pencils. They were encouraged to draw arrows to solve the different grid stories. The children had to get the dog to the kennel, without touching the shaded blocks.*

Name:_____

Grid #1



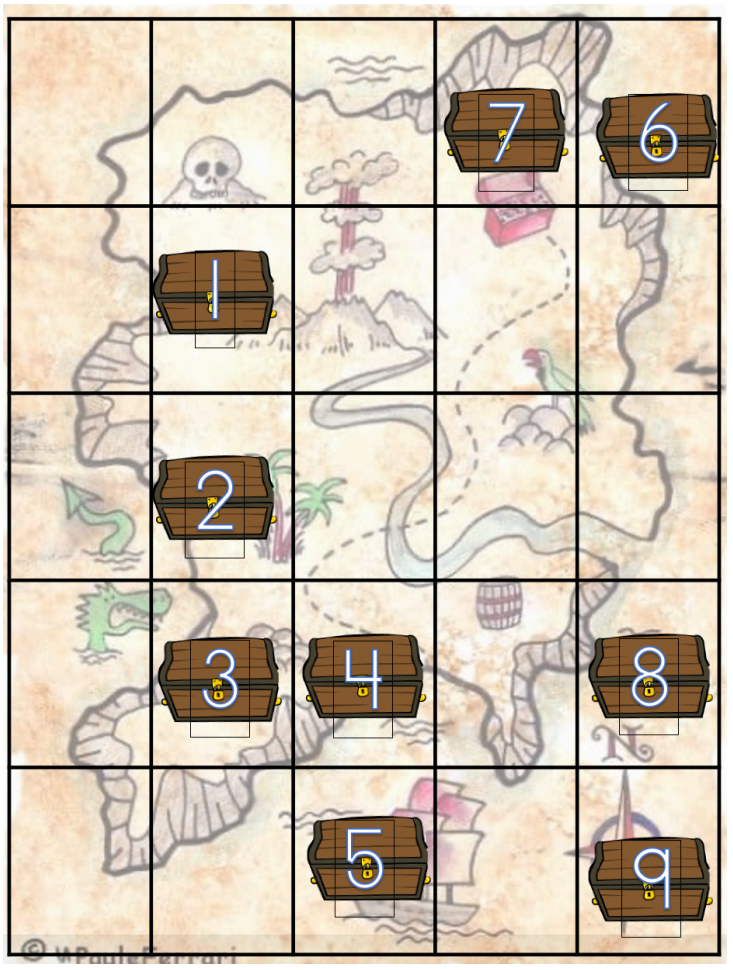
(Critical Thinking)

LESSON TWO

Activity 2:		
Context	Topic:	*Pirate*
	Total Activity Time:	*30 minutes*
	Number of learners:	*6 learners*
	Resources used:	• *coding critters* • *plastic pirate toys (plastic skeletons, plastic gold coins, plastic snakes, plastic jewels)* • *floor grid* • *grid #3* • *pencils* • paper treasure chests

		• LEGO • Pirate map • Pirate map grid • Pirate rings
Aims	• *basic understanding of what the robot can do* • *direction (forward, backwards, left, right)mainly forward, right and left.* • *Listening to instruction* • *understanding of the use of a grid. One block= one step/action* • *develop their problem solving skills* • *how to construct own sequence* • *how to manipulate a coding critter*	
Plan	*<u>Introduction: (5 minutes)</u>* *Introduce the theme of the lesson… pirates.* *The introduction focuses on the children's understanding of their right and left sides. This is the terminology that will be enforced in the rest of the lesson. The children will line up on a tapped line. They will be asked to raise (their arms or legs) on their right and left side. It will start slow and increase to a faster rate. The children will each be given a pirate ring. The ring must be placed on the right hand. This will aid in the children remembering their right and left side.* *<u>Main:</u>* *Activity 1: Pirate grid* • *A 5x5 block grid is tapped on the floor. Different boxes (treasure chests) will be placed in different blocks. Each chest will have a number written on. Inside each chest will be a series of surprises or scares. Some has "treasure inside" which would be plastic coins or plastic jewels. Or they could have plastic skeleton toys or plastic toy snakes.* • *The children will work in pairs. One is a pirate that must moves across the 5x5 grid. The other is a treasure map reader. The map reader will select a coin that has a number on and will use a map to guide the pirate (their teammate) to the correct*	

treasure chest. The children will take turns being the pirate and being the map reader.



Activity 2: LEGO Boat

- *The children will be given a box of LEGO and posed with the task of building their own mini pirate ship.*
- *The children are encouraged to be creative and build a pirate ship however they want.*
- *The teacher will ask open-ended questions regarding the creation they made and why it is a pirate ship.*

Activity 3: Pirate Coding Critter

- *The children will be given a problem that they can solve by trial and error.*
- *The problem=* ***Can you code your critter to move to the pirate cave and back?***
- *The children, working in pairs, must take turns and try get the coding critter to move to the pirate cave and back.*
- *This is all by trial and error. The children have a starting point and will keep retuning to start at this point until they get it right. There is no correct way of getting to the pirate cave. The children can choose their own course, whether it's a forwards*

and backwards course or whether the critter must move forward and turn around.

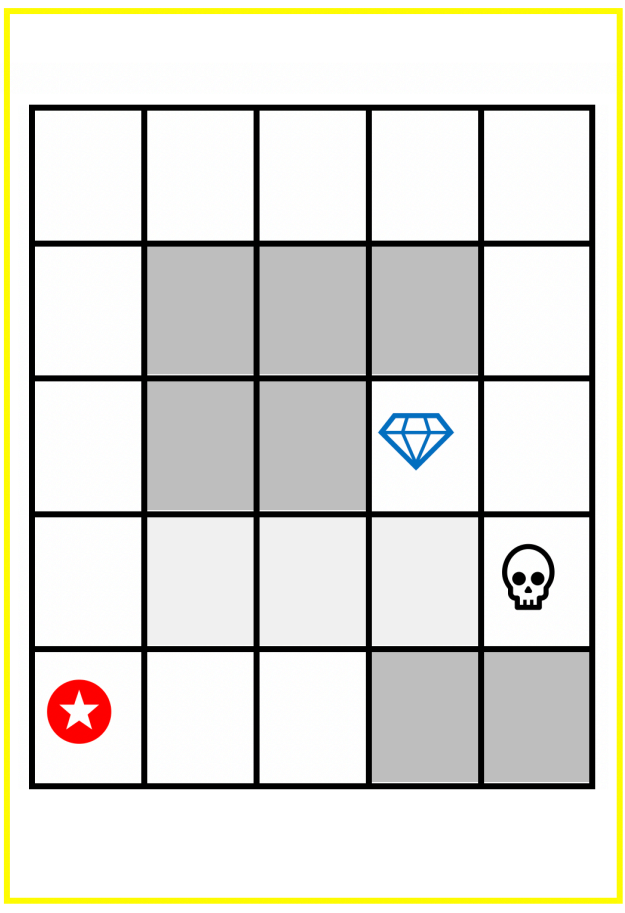
- *Communication is encouraged between the children.*

Activity 4: Pirate Map

- *The children will receive a pirate map. It was a basic grid on top of a pirate map. The children will work in pairs.*
- *One child will choose a block where the treasure should be placed.*
- *Using a coding critter and linear blocks. The children will draw a sequence with arrows to retrieve the treasure.*
- *The one child will be writing the arrows and the other child will be in charge of coding the critter. The children will take turns, alternating roles.*

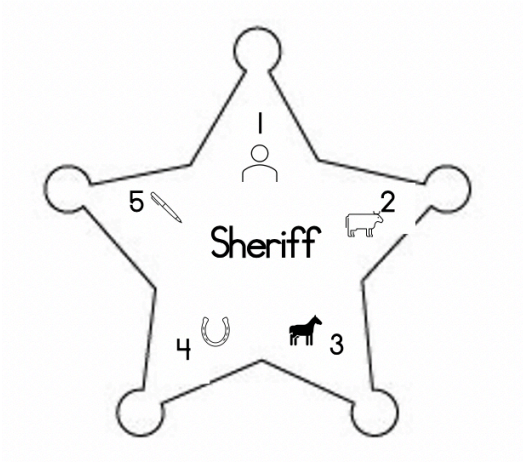
<u>Conclusion: (5 minutes)</u>

The children will each receive a grid. Using arrows, they must create a path to retrieve the treasure (diamond) and not get the dangerous skull.



LESSON THREE

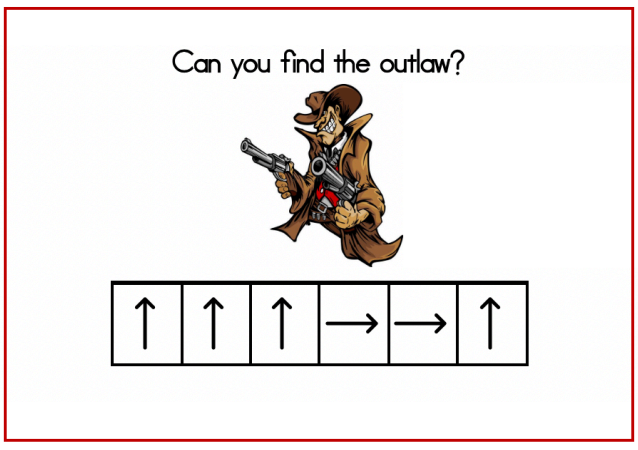
<table>
<tr><td colspan="3">Activity 3:</td></tr>
<tr><td rowspan="4">Context</td><td>Topic:</td><td>Western Cowboy & Cowgirls</td></tr>
<tr><td>Total Activity Time:</td><td>30 minutes</td></tr>
<tr><td>Number of learners:</td><td>6 learners</td></tr>
<tr><td>Resources used:</td><td>• coding critters
• plastic horses
• floor grid
• grid #4
• pencils
• Western Wanted cards
• LEGO
• Sheriff Badges</td></tr>
<tr><td>Aims</td><td colspan="2">• Turning vocabulary
• The ability to follow a sequence
• The skill to think and plan ahead with the relative sequence
• Construction of own sequence
• The ability to manipulate the coding critter to turn around
• Ability to discover a route in a grid using arrows</td></tr>
<tr><td>Plan</td><td colspan="2"><u>Introduction: (5 minutes)</u>
Introduce the theme of the lesson- Cowboys and cowgirls (The Wild West). The introduction focuses on the children’s remembrance of the vocabulary when explaining to your friend where to turn. of their right and left sides. This is the terminology that will be enforced in the rest of the lesson. The children will line up on a tapped line. They will be asked to follow the instructions the teacher says. They will then take turns instructing the other children. The children will also be given a sheriff badge. This badge will show the children the 5 activities that they will be completing. Each activity will be explained beforehand. The children will be given 5 minutes for each activity. The timer will go off and the children will move. Crossing off each activity was they complete it.</td></tr>
</table>



<u>Main:</u>

Activity 1: Most Wanted Scramble

- *A 4x4 grid is placed on the floor with "Most Wanted" picture cards. The cards are placed upside down. There is one outlaw in the pack of cards. The other cards are cartoon characters or pictures of the coding teachers. If the child picks up the outlaw card, they get a point. If they pick up a card that isn't the outlaw, they don't get a point.*
- *The children will work in pairs.*
- *They first will work together to follow the arrows that were given by the teacher to find the outlaw.*
- *Once the outlaw is found they will take turns. One will choose a new position to place the outlaw and draw arrows leading to the new position, while the other closes their eyes. Once the arrows are completed the one who closed their eyes will use the arrows to find the outlaw. The children will take turns placing the outlaw and finding him.*

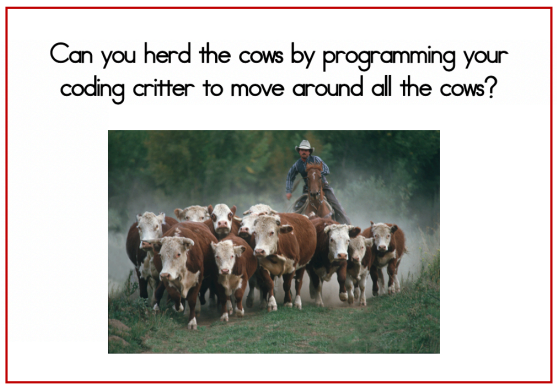


<u>(The arrows given by the teacher. The picture above is the outlaw that must be found).</u>

(The different "Most Wanted" cards).

Activity 2: Cattle Herding

- *For this activity the children are encouraged to get the coding critter to go around all the "cattle".*
- *Cow cards are placed on the floor. The children have to program the coding critter to go around all the cow cards. The children complete this activity through trial and error.*

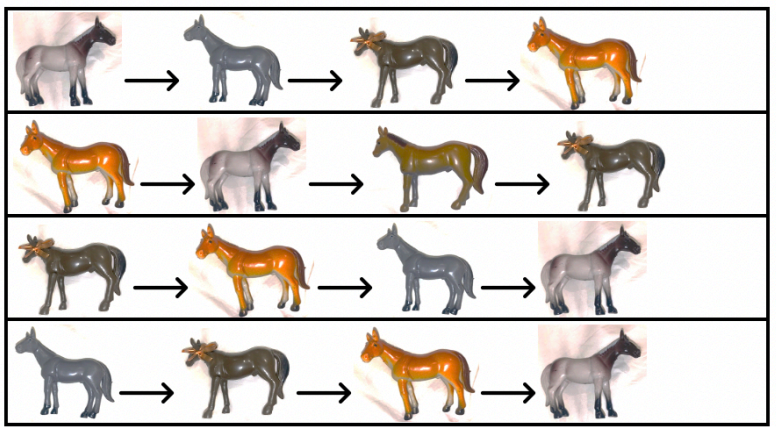


Activity 3: Coding Critter Horse Feeding

- *For this activity the children are posed with the question to feed the horses.*
- *The children are given different strips that show the order of the different horses that need to be fed.*
- *The children will using a coding critter to move between the different horses, to tap(feed) the horse.*
- *The children, working in pairs, must take turns and try get the coding critter to move to different horses and in the correct order, without knocking over the incorrect horse.*
- *Communication is encouraged between the children.*

Time to feed the horses!

Can you program the robot to move to each horse to feed? Once your coding critter touches the robot you can leave some hay for the horse.



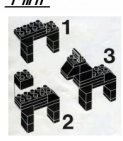
(The different strips, that show the order that the horses need to be fed).

Activity 4: LEGO: Can You Build a Horse?

- *The teacher poses the children with the task… "Can you build a horse out of LEGO?"*
- *The children are encouraged to make their very own creations. The teacher did give the learners a hint.*
- *The teacher will ask open-ended questions regarding the creation they made and why it looks like a horse.*

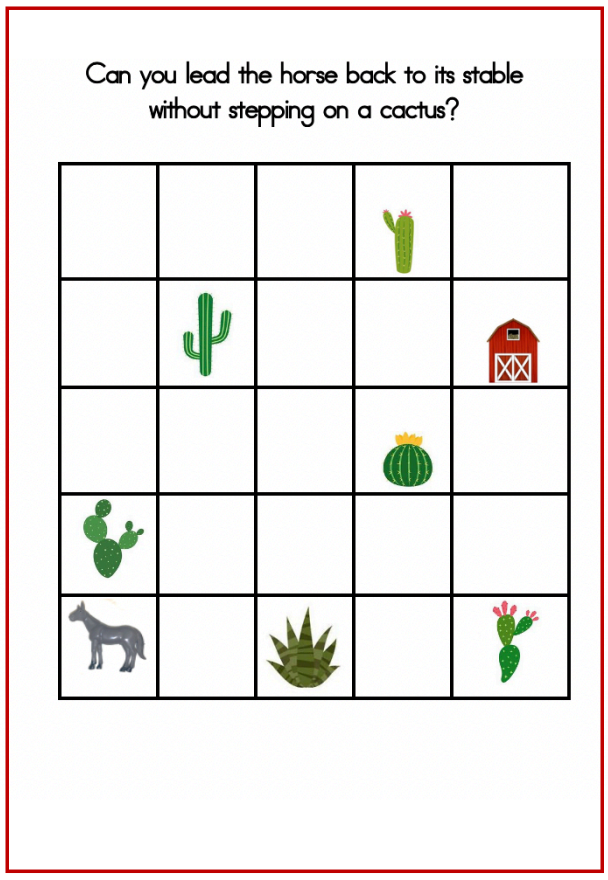
Every cowboy or cowgirl needs a horse!
Can you build a horse out of LEGO?

"Hint"



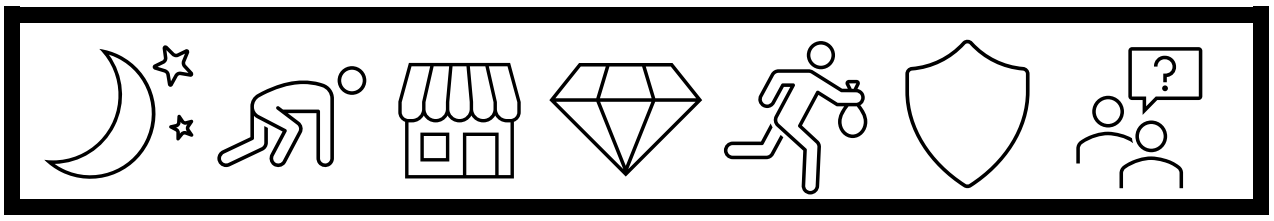
Conclusion: (5 minutes)

The children will each receive a grid. Using arrows, they must create a path to get the horse to the stable without walking into a cactus. There are multiple ways and the children are encouraged to come up with a unique and fun way. For this activity we encouraged the children to

	compare with one another, can't look at the different routes that were discovered 

LESSON FOUR

Activity 4:		
Context	Topic:	*Detectives*
	Total Activity Time:	*30 minutes*
	Number of learners:	*6 learners*
	Resources used:	• *Coding Critters* • *floor grid* • *sequence strips* • *pencils* • Board with different taped lines to jewel • Picture cards with one picture jewel card • LEGO • Grid
Aims	• *Direction vocabulary* • *Increase in confidence regarding the child's understanding of a grid.* • *Use and manipulate arrows when creating their own route*	

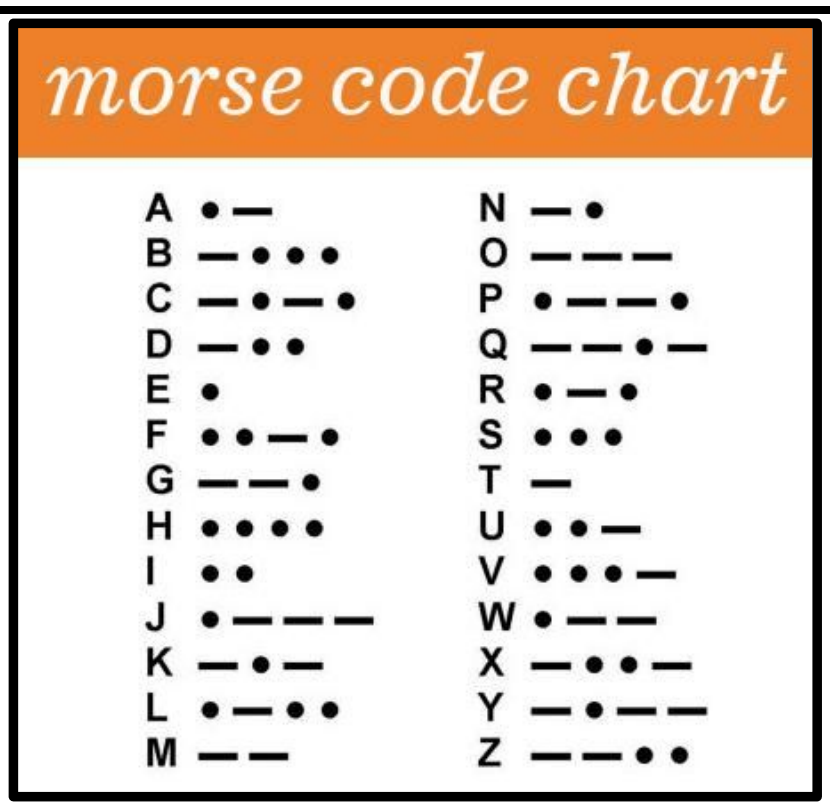
	• *Manipulate the Coding Critter to do what the child desires the robot to do.*
Plan	*<u>Introduction: (5 minutes)</u>* *<u>Story about Peter the Cheater, the jewel thief.</u>* *The teacher will give the children a slip with the images below. The children work in pairs to decode the pictures and tell the story the way they think it happened, using the pictures as clues. The teacher will then tell the learners to correct order of events.*  *<u>Main:</u>* *Activity 1: Code Catching* • *For this activity the children are encouraged to get the coding critter to travel along the lines of different courses.* • *The children must try catch the jewel thief. Using the coding critter, they must program the robot to follow along the lines to the thief.* • *The children complete this activity through trial and error.* *Activity 2: Peter the Cheater code breaker* • *Once Peter the cheater was found he had 16 robbery bags. Using the arrows can you find the bag with the jewel inside?* • *A 4x4 grid is placed on the floor with picture cards. The cards are placed upside down. There is one card that has a jewel on it. If the child picks up the jewel card, they get a point. If they pick up a card doesn't have a jewel they don't get a point.* *Activity 3: LEGO: Can You Build a Key?* • *The teacher poses the children with the task… "Can you build a key out of LEGO?"* • *The children are encouraged to make their very own creations.* • *This key will be used to lock Peter the Cheater away.*

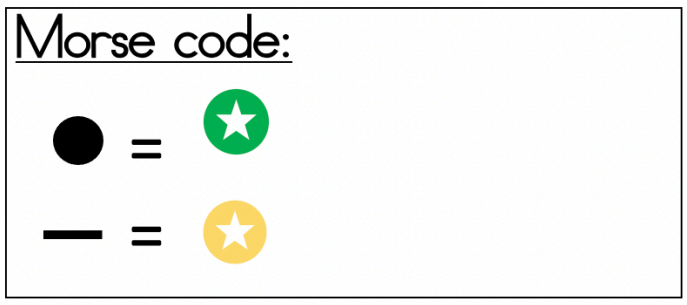
	• *The teacher will ask open-ended questions regarding the creation they made and how can it lock Peter the Cheater away.* • <u>*Conclusion:*</u> *Jewel Thief* • *The teacher introduces the activity with a story like introduction.* *"Some new evidence has been handed to the police to find Peter the cheater. Can you listen carefully? Once I have finished telling the story can you work in pairs to create a course that you think Peter the cheater took and discover where he is finding now. Once stealing the jewel we think Peter the cheater went right to a restaurant, at the restaurant he ate a big juicy burger. We believe he then went to a hat shop and bought a new disguise. We found burger sauce all over the shop. We think Peter the Cheater then went and got an ice-cream before hiding out in a wooden cabin close by. Which cabin do you think he is hiding in? Can you draw the course that Peter the Cheater took?* • *Using arrows, they must create a path to get the correct cabin that Peter the Cheater is hiding in, and they must also have the correct course. There are multiple ways, and the children are encouraged to come up with a unique and fun way. For this activity we encouraged the children to compare with one another and collaborate.*

LESSON FIVE

Activity 5:		
Context	Topic:	*Jungle Rangers*
	Total Activity Time:	*30 minutes*
	Number of learners:	*6 learners*
	Resources used:	• *Coding Critters*

		• *floor grid* • *pencils* • LEGO • Beads • String • Grid • Board with line to jewel for conclusion
Aims	• *Child is comfortable completing a grid with the correct arrows* • *Child can manipulate a Coding Critter* • *Child can confidently design and construct with their own creativity an object out of Lego.* • *Learners are understanding the concept of code and to break code (decode)*	
Plan	*<u>Introduction: (5 minutes)</u>* *The children will do a "if I do this" ... you do that game. It Is similar to Simon Says.* *<u>Main:</u>* *Activity 1: Animal Tracking* • *For this activity the children use a coding critter to track different animals. Each child will receive a checklist of four animals. They must each program the coding critter to follow the animals tracks and to reach the animal. Once they have correctly coded the coding critter to reach the specific animal, the child can check the animal off the list.* *Activity 2: Beads* • *Using morse code the children will bead together a bracelet with their names on.*	





Activity 3: Game-Drive Story

- *The teacher introduces the activity with a story like introduction.*

Story:

We went on an exciting game drive and saw some fun and interesting animals. Can you map all the animals that you saw on our game drive in the correct order? Beware... don't get an animal that we didn't see. When we started our game drive we all climbed into our trusty game viewer vehicle. This will keep us safe, as well as let us see all the animals clearly. The first animal we saw was a giraffe. It was gracefully eating from the top of some very tall trees. Next we had to pass through a river and there we saw some crocodiles lying on the banks of the river. It looked like they were tanning. At the river we also saw the some cute eyes pop out from the top of the water. Wow! We saw some hippos! After we had passed through the river we stopped a pride of lions that were relaxing in the shade under a big umbrella tree. The last animal we saw was a very special animal that is endangered. We are trying our very best to look after these animals and protect them poachers who want their special horn. We saw the incredible rhino! After seeing all these incredible animals we decided it was time to go back to the camp site and relax in our cool tent.

- *Using arrows, the children must create a path to show the correct order of the animals they saw. The grid is similar to that of a game reserve map. The children must choose the correct path that was followed. There are multiple ways, and the children are encouraged to come up with a unique and fun way. For this activity we*

encouraged the children to compare with one another and collaborate afterwards.

Activity 4: Game viewer

- *The teacher poses the children with the task… "Can you build a game-viewer out of LEGO?"*
- *The children are encouraged to make their very own creations.*
- *The children will be given images of game-viewers for inspiration in building their own creations.*
- *The teacher will ask open-ended questions regarding the creation and encourage the children to explain their creations in detail.*

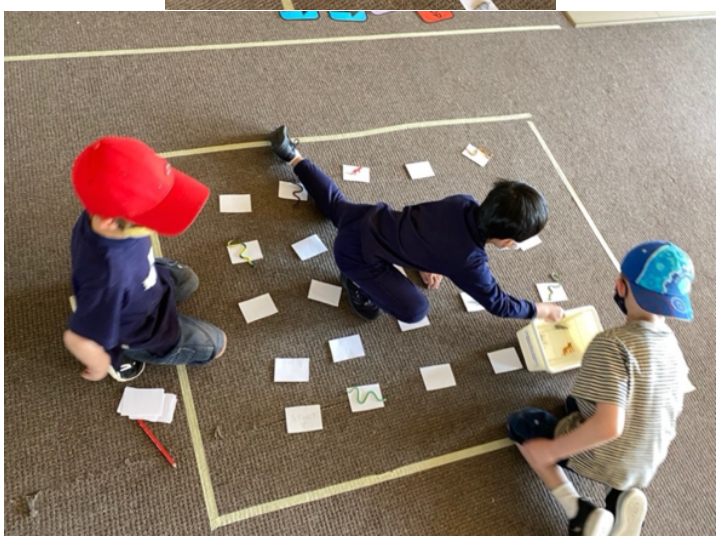
<u>Conclusion: (5 minutes)</u>

Story Line- Race to The Secret Lion Jewel

The children will be posed with the challenge of getting to the jewel first. The children have to code their coding critter to reach the jewel first. If their coding critter stops before the jewel or if their coding critter doesn't end on top of the jewel, they must start again. The winner goes to the next round. The final winner receives a prize.

APPENDIX D - PHOTO JOURNAL

LESSON ONE

Lesson 1	
Photos	**Description**
	**Introduction- learners played a game similar to "Simon says"- focusing on direction instructions. The learners caught on pretty quickly.**
  	**Learners completing activity 1- the snake figurine grid. Researcher assisting with little guidance. The learners loved having the physical snake figurines.**

Introduction to robots. Learners exploring the Coding Critter for the first time. There was such excitement to work with a robot. Would recommend more time to explore and play.

Learners posed with challenge to get the Coding Critter to follow some arrows.

Learners were excited to work with a robot and were so fascinated.

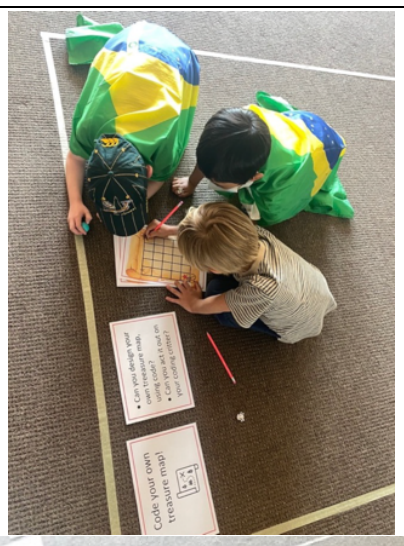
Learners worked together and discussed with one another.

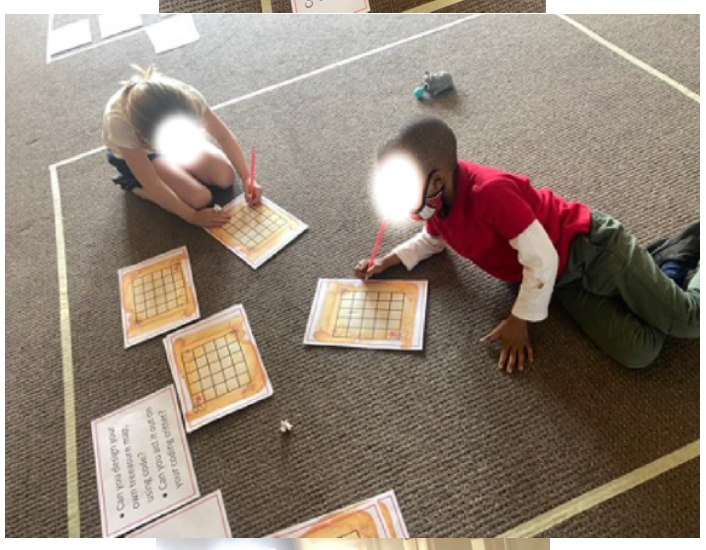
Learners first followed a sequence that the teacher created of different coding floor tiles. The learners then created their own sequence using the floor tiles.

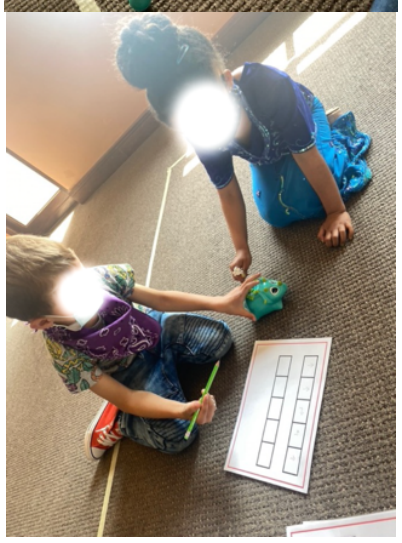
Learners were eager to complete the paper grid, and take it show to their parents what they did.

LESSON TWO

Lesson 2	
Photos	**Description**
   	**The first activity was a grid taped to the floor. The learners received a map replicating the grid. The learners had to guide their friend to the correct treasure box they chose.** **Learners were eager to receive the treasure. It was a challenge that was placed in context. The learners had great fun, and tried to guide their friend as well as they could.** **Learners loved the theme and got captivated in the lesson.** **The second activity encouraged the learners to build a pirate ship out of Lego. Learners felt like it was a bit challenging, however some of the learners really enjoyed this task.** **For the third activity the learners had to code the robot to reach the caves and back. This encouraged the learners to use the forwards and backwards button. Learners could easily code the robot forward and backwards and they often tried to create unique sequences.**



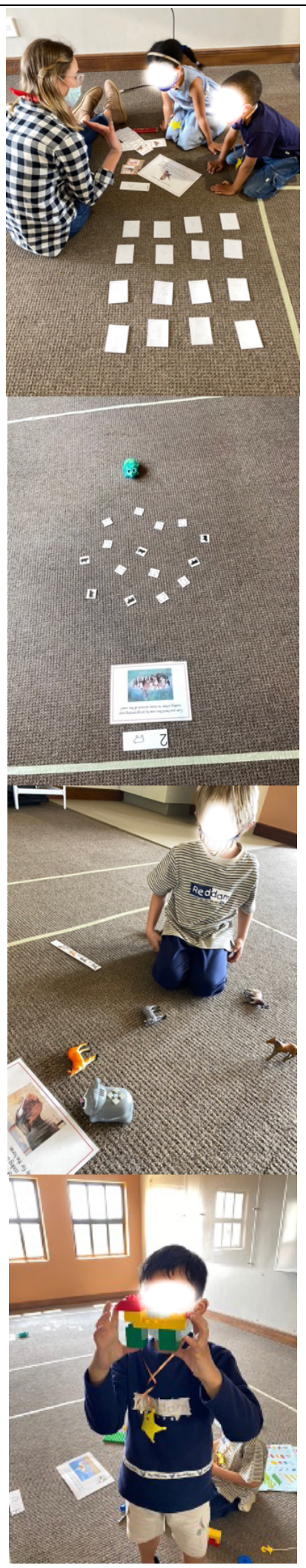


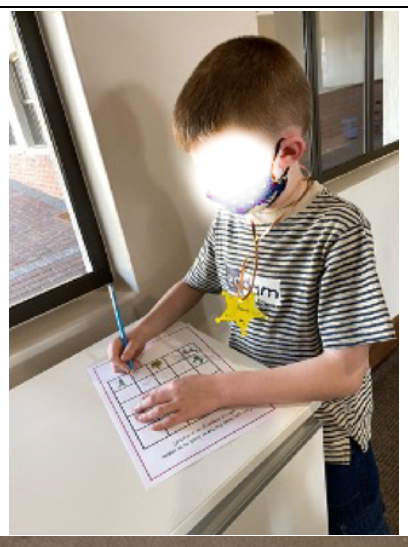
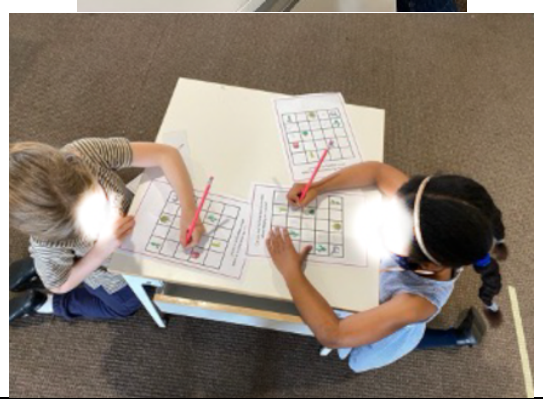


In the fourth activity the learners were given a grid of a basic pirate map.

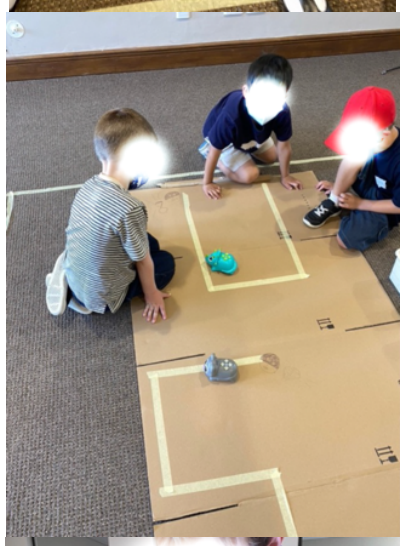
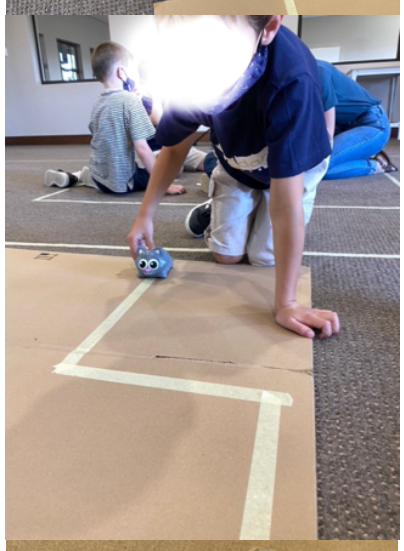
One child will “hide” some treasure on the grid. The children will work together to create the sequence on the grid to get to the treasure. Then using a Coding Critter the children will code the robot to follow the same sequence.

LESSON THREE

Lesson 3	
Photos	**Description**
	**The first activity has a 4x4 grid, which is placed on the floor with "Most Wanted" picture cards. All the cards are placed upside down. There is one outlaw on one of the cards. The children follow a sequence to find the outlaw card. After finding the outlaw card, the other children then take turns hiding it in between the other cards and creating their own sequence for their friend to follow.** **The second activity encourages the child to code the Coding Critter to move around the picture cow cards. The learners found this activity challenging as they had to code around the different pictures and make sure that there is enough room.** **The third activity got the children to code the robot to touch the different horses, to "feed" them.** **In the fourth activity the children built their own horses out of Lego. The learners found this to be fairly easy.** **For the conclusion of the lesson, the children completed a grid. Using arrows**

 	**they got the horse to the barn without touching the cactus.**

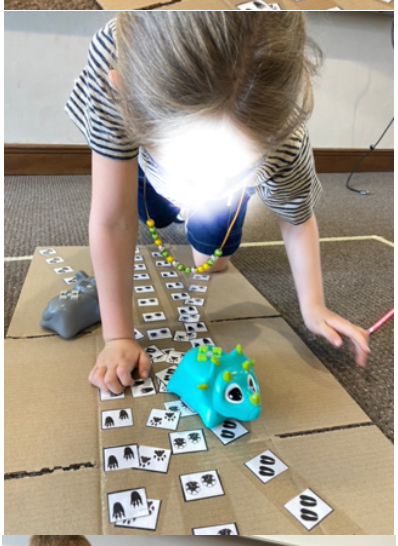
LESSON FOUR

Lesson 4	
Photos	**Description**
   	**For the introduction the learners got a sequence strip filled with different icons/images. The learners had to try decode the strip to explain the sequence of events that happened that night. The theme was about a thief called Peter the Cheater and the missing jewel.** **The first activity included working with the Coding Critters. The children had to code the robot to stay on the taped line. The learners had great fun and it quickly turned into a competition or game.** **The third activity was a great success with the children. They loved trying to find the missing jewel. The children were given 4x4 grid, which was made up of picture cards. The cards are placed upside down. There is one card that has a jewel on it. If the child picks up the jewel card, they get a point. If they pick up a card doesn't have a jewel, they don't get a point. The child must use a sequence strip with arrows to find the jewel. This encouraged the learners to try make it difficult for their friend to find.** **Learners built a key to lock Peter the Cheater up. The key was made out of Lego. This activity to too easy for a lot of the learners. Therefore, multiple keys were made.**

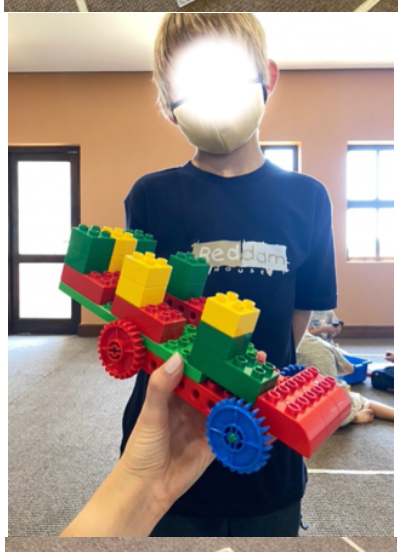
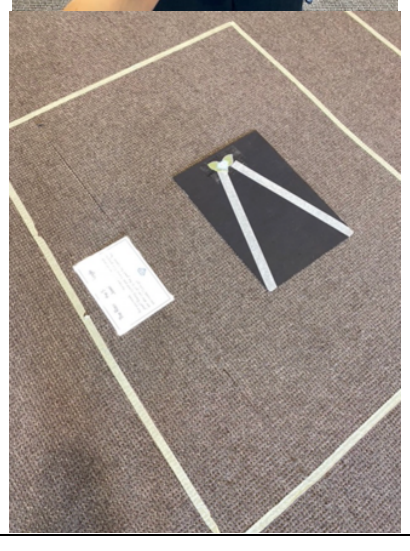
For the conclusion the learners worked with a grid. The learners listened to the story of what Peter the Cheater did and the order he did it in and they had to draw the arrows indicating the route that Peter the Cheater took. This was fun. The children were very excited to share their ideas

LESSON FIVE

Lesson 5	
Photos	**Description**
   	**For the introduction of the activity, the teacher read a story of a game drive and the different animals that were found (in order). The learners had to remember the sequence and draw the arrows to show the route. The learners loved this activity and could relate the game drive to ones that they have been on with their families.** **The children made their own necklaces out of a morse code template. the learners had to look at the code and try code their own names. The leaners loved working with different materials and a more table-top activity. The learners also got to take it home. They loved having evidence of their learning.** **The learners love working with robots. For this activity, the learners coded the Coding Critter to follow different animal tracks. The learners loved discovering the different animals and challenging each other to robot races, to see who can get their robot to touch the animal first.**



The learners built a game-viewer for their third activity. This activity was pretty challenging, but really allowed the learners to be creative. There were some beautiful creations. The learners even focused on details, like seats for all the people and even for the tracker (the man who sits in front).

  	**The conclusion of the lesson was a competition. The learners loved racing one another to who can reach the jewel first. The learners cheered each other on. There was great fun and enthusiasm.**

APPENDIX E - OBSERVATION SHEETS

LESSON ONE OBSERVATION

Date Of Observation: 11th September 2020	
Site: Reddam House Helderfontein- Classroom G13	
Activity Observed: Activity 1= Introduction	
Number Of Participants: 6	
Resources Used in Activity: floor tiles coding critters plastic animal figurines paper blocks grid #1 pencils	
Length Of Observation: 30 minutes	
Observation Notes:	
children engaged in discussions about coding & robotics. They were excited to engage with robots. Children are aware and comfortable with the COIVD-19 procedures in the classroom, such as sanitising hands and feet as they enter the classroom and move between activities. A few of the children still struggle identifying their lefts and rights Blocks on the floor helped the children identify the different activities.	*COVID-19 procedures* *Layout of lesson* *Group work*

Dividing the children into groups helped with managing them and the activities (teacher as a facilitator= learner-centered) Children rushed to complete activities they were excited about. Went over time to complete. Children also wanted to play and explore the Coding Critter, but not enough time. Activity focused on skills. Children were confident working with the coding floor tiles and didn't hold their interest. Not all activities were completed by all the learners. Too many activities and not enough time- children engaged in a bit more complex activities.	*Learner-centered* *Time* *Time* *Excitement or activity interest* *Time* *Time* *Time*

LESSON TWO OBSERVATION

Date Of Observation: 18th September 2020
Site: Reddam House Helderfontein- Classroom G13
Activity Observed: Activity 2= Pirate
Number Of Participants: 6
Resources Used in Activity: *coding critters* *plastic pirate toys (plastic skeletons, plastic gold coins, plastic snakes, plastic jewels)* *floor grid* *grid #3* *pencils* paper treasure chests LEGO Pirate map Pirate map grid Pirate rings

Length Of Observation: 30 minutes	
Observation Notes:	
Learners were excited and engaging with the theme of pirates. A deeper understanding occurred- activity had relevance. The learners' imagination spurred the activities on. The learners were excited. Fewer activities, which allowed learners to complete them all. Timer set= using the timer allowed children to complete each activity and if spare time to move on to the next activity, the children were given time to play that that activity. No spare activity was needed, in case all the activities were completed. Change of groups allowed other children to engage with new classmates. More concrete apparatus excited the learners and got them to actively engage and ask questions. Children could document what they had learner on the map- mix concrete and 2d resources. Also allowed the children to take home to show their parents. Ask questions, student centered allows teacher to move around and observe, as well as extend learning by asking questions. Monitor number of type of activities (5 min per activity was pretty short).	*Theme* *Time* *Time* *Groups* *Theme (concrete)*

LESSON THREE OBSERVATION

Date Of Observation: 8th October 2020
Site: Reddam House Helderfontein- Classroom G13

Activity Observed:

Activity 3= *Western Cowboy & Cowgirls*

Number Of Participants: 6

Resources Used in Activity:

coding critters

plastic horses

floor grid

grid #4

pencils

Western Wanted cards

LEGO

Sheriff Badges

Length Of Observation: 30 minutes

Observation Notes:

Theme= was successful and placed learning in a fun story-like context.	*Theme*
Concrete apparatus got children excited and engaged in each activity.	*Concrete apparatus*
Timer was effective and allowed children to complete all activities, however still not enough time. 5 min per activity is too short.	*Time*
Completing the concluding activity together as a group and not in pairs, got the children to engage and communicate with one another. The children compared their routes and it lead to a great discussion, instead of completing the activity in pairs.	*Group work*
Sheriff bag was used to monitor the activities completed- wasn't as effective as planned. Learners were eager to move between activities and forget to check the sheriff badge.	*Time*
In order to ensure each skill was met each activity focused on one of the 21st Century Thinking Skills.	

	Skills

LESSON FOUR OBSERVATION

Date Of Observation:15th October 2020
Site: Reddam House Helderfontein- Classroom G13
Activity Observed: Activity 4= *Detectives*
Number Of Participants: 6
Resources Used in Activity: *Coding Critters* *floor grid* *sequence strips* *pencils* Board with different taped lines to jewel Picture cards with one picture jewel card LEGO Grid
Length Of Observation: 30 minutes
Observation Notes:

Theme= children could construct own adventures. The children engaged well with the theme. Multiple activities linked to a main story- this allowed the children to fully emerge in scenario thinking and using 21st Century Thinking Skills in context. Lego activity was too easy. Learners lost interest early into the activity. Time management was difficult to manage as the sanitising for COVID-19 procedures does take a lot of time and the children lose interest in some of the activities, while with	*Theme* *Story* *Difficulty level* *Time*

the more popular activities the learners took longer and didn't want to leave. Too many activities offered. The children loved the main story. Lead to a lot of discussions and encouraged the children to use their imagination when thinking and discovering new routes.	*Amount of activities* *Story*

LESSON FIVE OBSERVATION

Date Of Observation: 22nd October 2020
Site: Reddam House Helderfontein- Classroom G13
Activity Observed: Activity 5= *Jungle Rangers*
Number Of Participants: 6
Resources Used in Activity: *Coding Critters* *floor grid* *pencils* LEGO Beads String Grid Board with line to jewel for conclusion
Length Of Observation: 30 minutes
Observation Notes:

Theme= jungle rangers. The children loved having a theme to work with. There was great excitement to each activity which held a piece of the story. The learners (both girls and boys) were motivated and excited. Activity 1= allowed the children to work independently but got excited to share which animal they tracked.	*Theme*

Morse code bracelet activity was completed on a table and not on the floor as usual. A change in the environment was constructive and got the children to settle down. Story activity gave the children relevance and encouraged discussion, listening and thinking. Time was much better managed. Children had enough time to move between activities. Some activities took shorter amount of time than others. Lego activity was difficult- the children got the opportunity to be incredibly creative and use their imagination. They loved it and loved discussing their creations with the teacher and classmates. The conclusion was effective. The children loved racing and competing with one another. It encouraged the children to discuss ideas with one another, as well as evaluate each other.	*Independent work opportunities* *Layout* *Story* *Time* *Creativity & activity difficulty* *Competitions & group work*

APPENDIX F - OBSERVATION

TEACHER A INTERVIEW PRIOR TO THE ACTIVITIES

Topic: Development of 21st century skills in Early Childhood Learners Through Coding and Robotics

RESEARCH QUESTION: How can coding and robotics support the development of 21st century skills in Early Childhood Education?

1	What does coding and robotics in early childhood education mean to you?
	Okay, so coding to me…when you say coding, I think of computer programming. That's the first thing that comes to mind. And robotics is anything robotic that moves in that manner.
2	What do you know about 21st century skills?
	Very little. I'm old school.
3	Do you believe the development of 21st century skills to be beneficial?
	Absolutely. Look, they definitely got their benefits. It's just getting your mind set behind it and following it and keeping up with it, because it's changing all the time. So, that's why I say I don't know much about it because, like I said I'm very old school, and I know the set things but not more. There's no formal training in schools, so how are we supposed to keep up with technology?
4	Do you believe there are opportunities for learners to communicate within the classroom?
	Yes. We very open with communication and I like them to have froward thinking and to ask on whatever subject that we doing and then when it comes to I don't know or somebody else doesn't know, then we use the modern technology like google and stuff.
5	Do you believe there are opportunities for learners to collaborate in the classroom?
	Yes. All the time. I think it's vital. Very very vital.
6	Do you believe there are opportunities for learners to think critically in the classroom?
	Yes and no. I feel we possibly don't have the correct concrete apparatus for them to assess and start thinking critical about it and how it works. I don't think we have advanced stuff in the class that encourages them in critical thinking.

7	Do you believe there are opportunities for learners to be creative in the classroom?
	Yes. All the time. All the time. I think it's also how I teach. I encourage that.

Questions related to the individual learner:

Participant A:		
Circle the number: *(1-poor, 2-fair, 3-average, 4-good, 5-excellent)*		
Content knowledge	Communication	**1.** 2. 3. 4. 5.
	Collaboration	1. **2.** 3. 4. 5.
	Critical thinking	**1.** 2. 3. 4. 5.
	Creativity	1. 2. **3.** 4. 5.

Participant B:		
Circle the number: *(1-poor, 2-fair, 3-average, 4-good, 5-excellent)*		
Content knowledge	Communication	1. **2.** 3. 4. 5.
	Collaboration	1. **2.** 3. 4. 5.
	Critical thinking	1. 2. **3.** 4. 5.
	Creativity	1. 2. **3.** 4. 5.

Participant C:		
Circle the number: *(1-poor, 2-fair, 3-average, 4-good, 5-excellent)*		
Content knowledge	Communication	1. 2. 3. **4.** 5.
	Collaboration	1. 2. 3. **4.** 5.
	Critical thinking	1. 2. 3. **4.** 5.
	Creativity	1. 2. 3. **4.** 5.

Participant D:		
Circle the number: *(1-poor, 2-fair, 3-average, 4-good, 5-excellent)*		
Content knowledge	Communication	**1.** 2. 3. 4. 5.
	Collaboration	1. 2. **3.** 4. 5.
	Critical thinking	1. **2.** 3. 4. 5.
	Creativity	1. 2. 3. **4.** 5.

TEACHER B INTERVIEW PRIOR TO THE ACTIVITIES

Topic: Development of 21st century skills in Early Childhood Learners Through Coding and Robotics

RESEARCH QUESTION: How can coding and robotics support the development of 21st century skills in Early Childhood Education?

1	What does coding and robotics in early childhood education mean to you?
	Okay, so I would say it is. it's got a lot to do with planning and being innovative with your thinking. And helping the kids to be proactive in the way that they think and who they want to be. I think it helps with all those kinds of things.
2	What do you know about 21st century skills?
	That again is teaching them to be independent thinkers, to be aggressive and proactive. Also I feel like a lot of kids now a days, in school, especially preschool children are going to have to create their own jobs. So I think it's part of that whole philosophy.
3	Do you believe the development of 21st century skills to be beneficial?
	Absolutely. A 100%. I mean in today's world and the way everything moves so fast it is so progressive. I mean if you just look at the development and speed of technology they absolutely need to develop or acquire those skills.
4	Do you believe there are opportunities for learners to communicate within the classroom?
	Like right now. I think yes. I think so all the time during play time even when they are doing group work, they playing with the blocks, when they doing art they talk to each other about their ideas and colours.
5	Do you believe there are opportunities for learners to collaborate in the classroom?
	Yes. This year has kind of changed that a bit. Because of COVID they quite separated. But before yes definitely, early on in the year.
6	Do you believe there are opportunities for learners to think critically in the classroom?
	Yes definitely. I always give the opportunities to make their own decisions about things and to decided what they going to do. We decided our provocations together, but then even further to that we talk about smaller things in our provocation. Like what we going to learn about and how we going to do it.
7	Do you believe there are opportunities for learners to be creative in the classroom?

	Definitely. Absolutely. Especially in the Reggio environment. It can be very creative. It can be in everything. We had an exercise the children had to look at a picture and create their own story. Some of them were super creative. Cole was one of them. It was lovely to see how creative they were, not just in art but in other opportunities in the classroom.

Questions related to the individual learner:

Participant E:		
Circle the number: *(1-poor, 2-fair, 3-average, 4-good, 5-excellent)*		
Content knowledge	Communication	1. 2. 3. 4. 5.
	Collaboration	1. 2. 3. 4. 5.
	Critical thinking	1. 2. 3. 4. 5.
	Creativity	1. 2. 3. 4. 5.

Participant F:		
Circle the number: *(1-poor, 2-fair, 3-average, 4-good, 5-excellent)*		
Content knowledge	Communication	1. 2. 3. 4. 5.
	Collaboration	1. 2. 3. 4. 5.
	Critical thinking	1. 2. 3. 4. 5.
	Creativity	1. **2.** 3. 4. 5.

Participant G:		
Circle the number: *(1-poor, 2-fair, 3-average, 4-good, 5-excellent)*		
Content knowledge	Communication	1. 2. 3. 4. 5.
	Collaboration	1. 2. 3. 4. 5.
	Critical thinking	1. 2. 3. 4. 5.
	Creativity	1. 2. 3. 4. 5.

TEACHER A INTERVIEW AFTER ACTIVITIES

Topic: Development of 21st century skills in Early Childhood Learners Through Coding and Robotics

Questions related to the individual learner:

Participant A:		
Circle the number: *(1-poor, 2-fair, 3-average, 4-good, 5-excellent)*		
Content knowledge	Communication	1. 2. 3. 4. **5.**
	Collaboration	1. 2. 3. **4.** 5.
	Critical thinking	1. 2. **3.** 4. 5.
	Creativity	1. 2. **3.** 4. 5.
Communication- it has been quite tricky with her. She has had hurdles she's had to overcome. So, before she was incredibly chatty but not focused. Whereas now she is way more focused. She communicates a lot better. When she thinks of topics first before asking and talking about it. It first I said one, now I will say almost five. *Collaboration- once again, before not great, I said a two, but a lot better now, probably a four.* *Critical thinking- her critical thinking as non-existent so a one, but maybe average now so a three.* *Creativity- her creativity… she has always been creative, so I would sort of average and now there hasn't been a huge change in it.*		

Participant B:		
Circle the number: *(1-poor, 2-fair, 3-average, 4-good, 5-excellent)*		
Content knowledge	Communication	1. **2.** 3. 4. 5.
	Collaboration	1. 2. **3.** 4. 5.
	Critical thinking	1. 2. **3.** *4.* 5.
	Creativity	1. 2. 3. 4. 5.
Communication- okay. Very verbal. I won't say constructive communication. So before it is I know everything. He thinks that he knows everything, but he doesn't actually. So he's very quick to say, "Oh I know that" and communicate but geos off topic. He doesn't stay on topic, because he doesn't know about it. *Collaboration- it has improved slightly, so I would say a three.* *Critical thinking- he's not bad. So let's say a four now. I will give him that.* *Creativity- he's average in his creativity and there's been no improvement.*		

Participant C:
Circle the number:

(1-poor, 2-fair, 3-average, 4-good, 5-excellent)		
Content knowledge	Communication	1. 2. 3. 4. **5.**
	Collaboration	1. 2. 3. 4. **5.**
	Critical thinking	1. 2. 3. 4. **5.**
	Creativity	1. 2. 3. 4. **5.**
Communication- always been good. So I would say five, it has improved. *Collaboration- also a five.* *Critical thinking- his critical thinking is awesome. He's brilliant. So a five.* *Creativity- his creativity has just has just risen. So a five.*		

Participant D:		
Circle the number: *(1-poor, 2-fair, 3-average, 4-good, 5-excellent)*		
Content knowledge	Communication	**1.** 2. 3. 4. 5.
	Collaboration	1. 2. **3.** 4. 5.
	Critical thinking	1. 2. **3.** 4. 5.
	Creativity	1. 2. 3. 4. **5.**
Communication- a one. A bit hard here. But one. There has been a slight improvement but not much. *Collaboration- her collaboration is okay. I would say average. There hasn't been vast improvement there.* *Critical thinking-isn't good. I would say a two before. And a slight improvement. So a three now.* *Creativity- she is creative. She is very creative actually. So, I will say a five.*		

TEACHER B INTERVIEW AFTER ACTIVITIES

RESEARCH QUESTION: How can coding and robotics support the development of 21st century skills in Early Childhood Education?

Questions related to the individual learner:

Participant E:		
Circle the number: *(1-poor, 2-fair, 3-average, 4-good, 5-excellent)*		
	Communication	**1.** 2. 3. 4. **5.**

Content knowledge	Collaboration	1. 2. **3.** 4. 5.
	Critical thinking	1. 2. 3. 4. **5.**
	Creativity	1. 2. 3. 4. **5.**

Communication- I think it's been incredibly beneficially for him. He was actually quite quiet and quite withdrawn. And he's really sort of come out of his shell. Think it's really good. He was so interested in the book you had given. And he would get really excited when he knew it was coding day. So it really helped him a lot, I think. A massive improvement.
Collaboration- I would say a three.
Critical thinking- he's always been a critical thinker. I would say a five.
Creativity- I think he has also become more creative. I mean the whole story thing also happened during the time that he was doing coding. And when he first came back after lockdown. He came back very quiet and reserved after lockdown and they started with coding, so I think it has helped.

Participant F:

Circle the number:
(1-poor, 2-fair, 3-average, 4-good, 5-excellent)

Content knowledge	Communication	1. 2. 3. 4. **5.**
	Collaboration	1. 2. **3.** 4. 5.
	Critical thinking	1. 2. 3. *4.* **5.**
	Creativity	1. 2. 3. **4.** 5.

Communication- it's quite difficult to tell because at the same time he started play therapy. So I'm not sure which, but a definite improvement. A massive improvement. And again always excited for coding. He loved coding. So I would say his communication was poor before but now much improved so a five. It could be a combination with the play therapy.
Collaboration- that probably moved to a three.
Critical thinking- he's a good critical thinker. Always. So probably a five now.
Creativity- creativity is difficult with him. If it is something concrete, he is very creative, but not if its fantasy or imagination. Like when we created robots in first term, he was very creative. He even put glitter gel in the top that was given his brain. What when he does to art and stuff he is off the wall. So I think coding was very good for him. Because he was doing that creative aspect that he enjoys, like building and planning. So I would say he ended with a four.

Participant G:

Circle the number:

(1-poor, 2-fair, 3-average, 4-good, 5-excellent)		
Content knowledge	Communication	1. 2. 3. **4.** 5.
	Collaboration	1. 2. 3. **4.** 5.
	Critical thinking	1. 2. 3. 4. **5.**
	Creativity	1. 2. 3. 4. **5.**
Communication- his communication improved. It's not that he doesn't communicate, but definitely more communicative afterwards. *Collaboration- he's kind of good with that so I would say a four. Because he also improved in that too.* *Critical thinking- he's also a really bright kind. I would say he jumped to five.* *Creativity- he's very creative. So I would say he moved to five.*		

APPENDIX G - FEEDBACK REPORT FOR PARENTS

WHAT WE DID IN CODING & ROBOTICS

THANK YOU SO MUCH FOR YOUR PARTICIPATION.

Lessons planned and presented by Embeth van der Wal
Data Collection for Masters Studies

FEEDBACK REPORT // NOVEMEBER 2020

02

PURPOSE OF THE STUDY

The purpose of this study is to develop guidelines to design activities in coding and robotics that support the development of 21st century skills. By developing guidelines for educators to successfully plan and present coding and robotic activities, this will better support the development of 21st century skills in early childhood learners, particularly in a South African context. This study will ultimately aid in equipping early childhood learners with vital skills for the future.

ABOUT THE LESSONS PLANNED

All the coding and robotics lessons planned focused on developing 21st century thinking skills in a fun and interactive way. We believe that these soft skills better prepare learners for the rapidly evolving digital world. Research argues that early childhood education plays a crucial role in equipping students with the soft skills necessary to create the foundation for lifelong learning, such as critical thinking, problem solving and collaboration. that is why we believe it is important to start developing these soft skills.

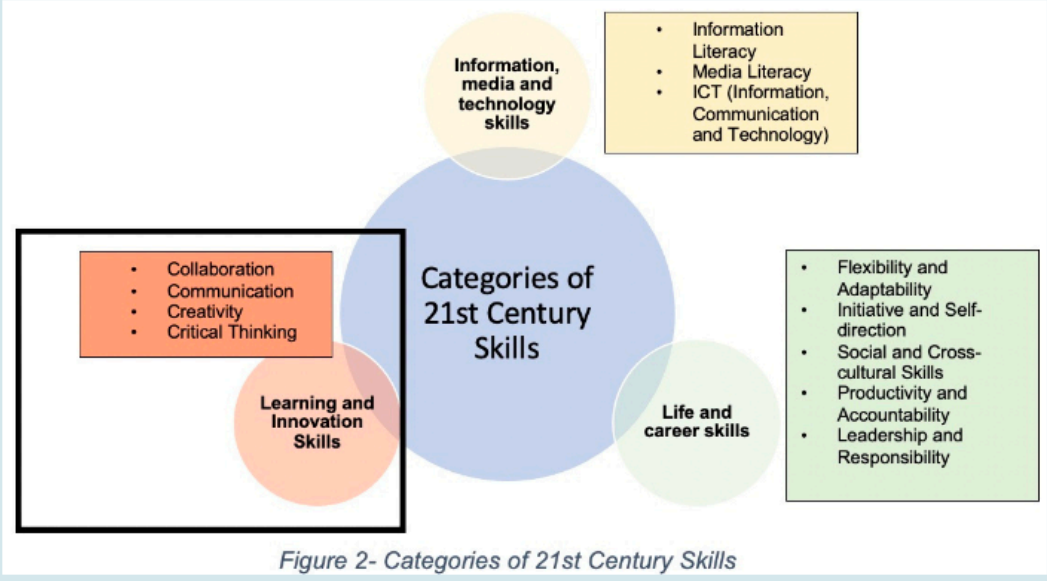


Figure 2- Categories of 21st Century Skills

FEEDBACK REPORT // NOVEMBER 2020

03

LESSON ONE:

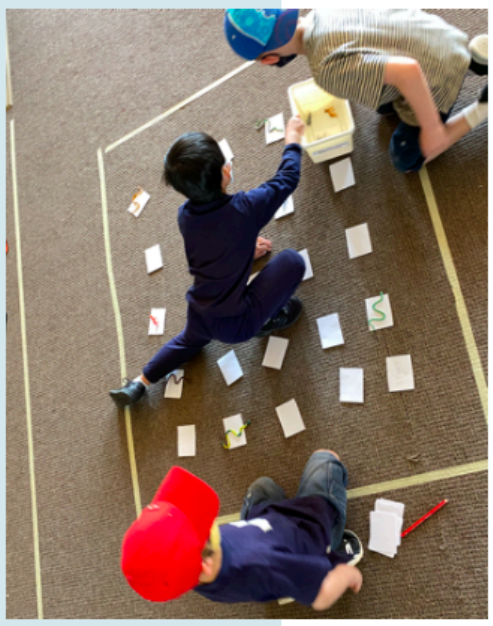
TOPIC: *Introduction to Coding & Robotics*

INTRODUCTION:

- *learners stood on a line that was taped on the floor. The teacher called out direction instructions.*
- *Instructions started with single instructions (forward, backwards, left, right)*
- *Instruction were then combined in pairs (e.g. forward, right)*
- *Instruction were then linked (forward, right, forward, forward, left)*

MAIN:

There were three different activities. The children were divided into pairs and they moved between the different activities.



ACTIVITY 1:

- *A grid was created with square blocks of white paper.*
- *Plastic animal figurines were placed randomly on the grid.*
- *The children took turns. One child was an instructor and the other was a collector. The instructor would stand and instruct the other child where to move in order to collect the animals as fast as they could. The collector would listen to the instructor and move around the grid with a bucket, collecting the animal figurines.*

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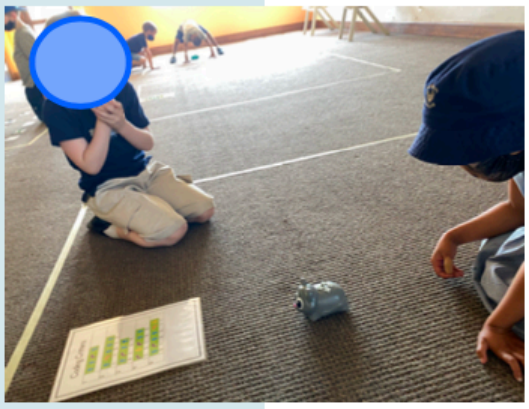
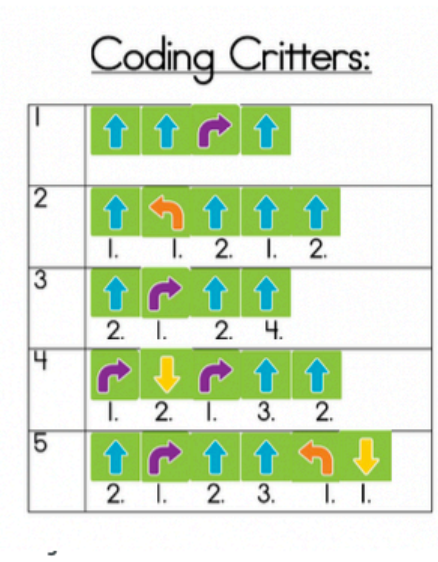
04

LESSON ONE:



ACTIVITY 2:

- *The children continued to work in pairs. They were given a Coding Critters with different sequencing strips that they were required to work through. There was very little instruction from the teacher. The children had to discover how to make the Coding Critters move. The children took turns solving the different sequences.*
- *The children were then encouraged to create their own sequences. One child would use the arrow cards to plan their own sequence and the other child would use the coding critter to act out the planned sequence. The children took turns in alternating their roles.*



ACTIVITY 3:

- *There wer[illegible]designed for the children to follow. It is a fun activity, similar to hopscotch.*
- *The children were then able to design their own floor tile sequence for their friends to follow.*

CONCLUSION:

The children were given a grid and their own pencils. They were encouraged to draw arrows to solve the different grid stories. The children had to get the dog to the kennel, without touching the shaded blocks.

FEEDBACK REPORT // NOVEMBER 2020

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FEEDBACK FROM LESSON ONE:

SPECIFIC GUIDELINES WE DISCOVERED WHEN IMPLEMENTING THE LESSONS.

1. Dedicate time for the learners to engage in discussions about the activity.
2. Allowing the children to work in pairs encouraged them to continue to communicate and collaborate on the task at hand. The activities were learner-centred.
3. Time- children were rushed to complete actiivities that they were excited about and went over time at certain stations. Give the children time to play and explore regardless of the activity at hand.
4. Children were more comfortable following a floor tile instruction, than creating their own. Include more creativity led activities in future.

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LESSON TWO:

TOPIC: Pirates

INTRODUCTION:

The introduction focuses on the children's understanding of their right and left sides. This is the terminology that will be enforced in the rest of the lesson. The children will line up on a tapped line. They will be asked to raise (their arms or legs) on their right and left side. It will start slow and increase to a faster pace. The children will each be given a pirate ring. The ring must be placed on the right hand. This will aid in the children remembering their right and left side.

MAIN:

ACTIVITY 1:

- *A 5x5 block grid is tapped on the floor. Different boxes (treasure chests) will be placed in different blocks. Each chest will have a number written on. Inside each chest will be a series of surprises or scares. Some have "treasures inside" which would be plastic coins or plastic jewels. Or they could have plastic skeleton toys or plastic toy snakes.*
- *The children will work in pairs. One is a pirate that must move across the 5x5 grid. The other is the treasure map reader. The map reader will select a coin that has a number on and will use a map to guide the pirate (their teammate) to the correct treasure chest. The children will take turns being the pirate and being the map reader.*

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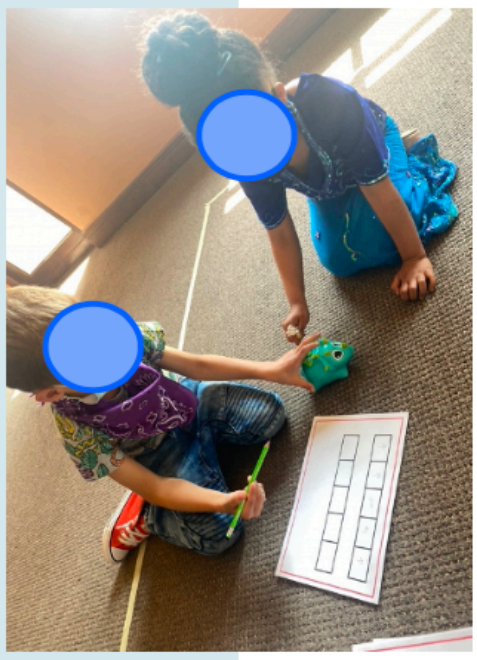
LESSON TWO:

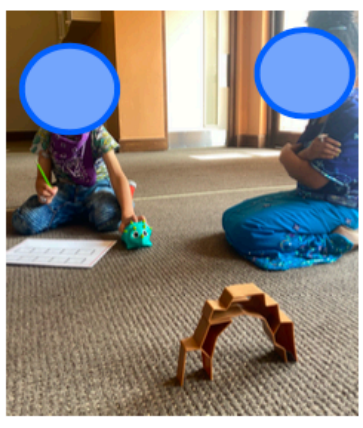


ACTIVITY 2:

- *The children will be given a box of LEGO and are given the task of building their own mini pirate ship.*
- *The children are encouraged to be creative and build a pirate ship however they want.*
- *The teacher will ask open-ended questions regarding the creation they made and why it is a pirate ship.*

ACTIVITY 3:

- *The children will be given a problem that they can solve by trial and error.*
- *The problem= Can you code your critter to move to the pirate cave and back?*
- *The children, working in pairs, must take turns and try get the coding critter to move to the pirate cave and back.*
- *This is all by trial and error. The children have a starting point and will keep returning to start at this point until they get it right (reach the cave and back). There is no correct way of getting to the pirate cave. The children can choose their own course, whether it's a forwards and backwards course or whether the critter must move forward and turn around.*
- *Communication is encouraged between the children.*



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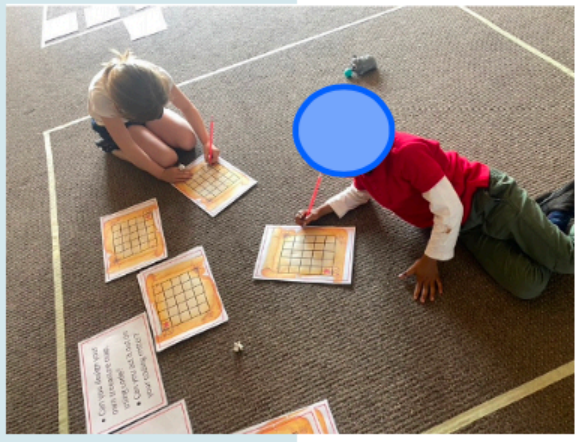
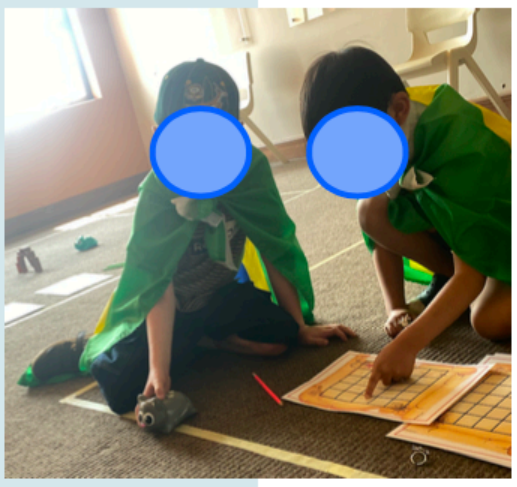
08

LESSON TWO:



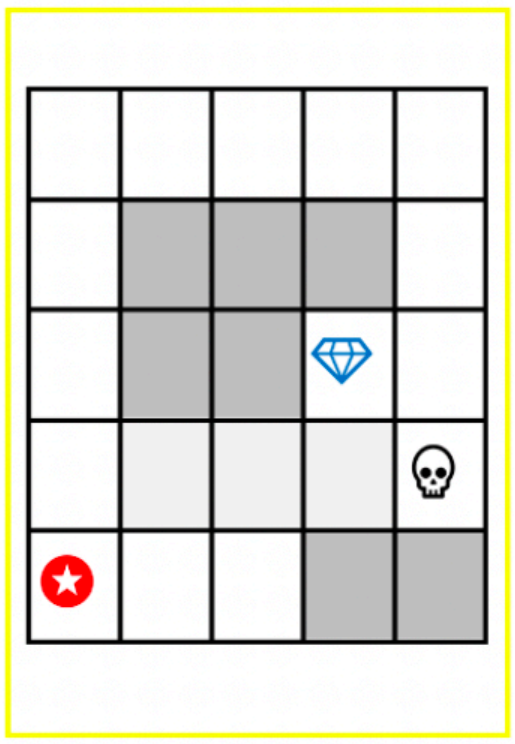


ACTIVITY 4:

- *The children will receive a pirate map. It was a basic grid on top of a pirate map. The children will work in pairs.*
- *One child will choose a block where the treasure should be placed.*
- *Using a coding critter and linear blocks. The children will draw a sequence with arrows to retrieve the treasure.*
- *The one child will be drawing the arrows and the other child will be in charge of coding the critter. The children will take turns, alternating roles.*

CONCLUSION:

The children will each receive a grid. Using arrows, they must create a path to retrieve the treasure (diamond) and not get the dangerous skull.



FEEDBACK REPORT // NOVEMBER 2020

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FEEDBACK FROM LESSON TWO:

SPECIFIC GUIDELINES WE DISCOVERED WHEN IMPLEMENTING THE LESSONS.

1. The use of a theme allowed the learners to immerse themselves in the task at hand, while allowing them to have fun and use their imagination.
2. The activities had a story with relevance.
3. Fewer activities while allowing the learners to complete the activities in a calm manner.
4. After the last lesson, we incorperated the use of a timer. This helped with time management as the children knew they couldn't move on from an activity until the time was up and they also couldn't stay at their favourite activity.
5. The use of other concrete apparatus encouraged the learners to actively engage with one another and ask questions (focuses on communication skills).
6. Not all activities had the same difficulty- manage this appropriately in future lessons.

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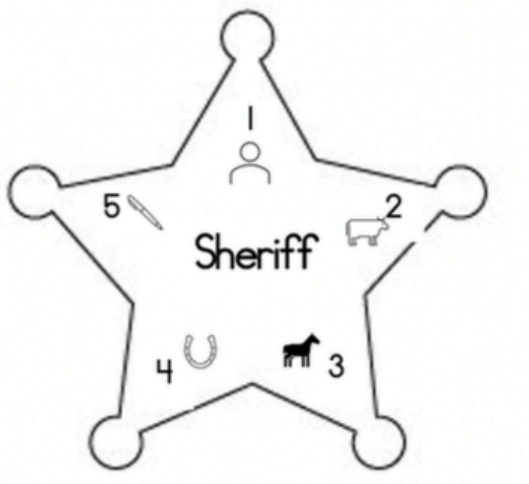
LESSON THREE:

TOPIC: *Western Cowboys and Cowgirls*

INTRODUCTION:

- *Introduced the theme of the lesson- Cowboys and cowgirls (The Wild West).*
- *The introduction focused on the children's remembrance of specific vocabulary when explaining to your friend where to turn. This is the terminology that will be enforced in the rest of the lesson.*
- *The children will line up on a taped line. They will be asked to follow the instructions the teacher says. They will then take turns instructing the other children.*
- *The children will also each be given a sheriff badge. This badge will show the children the 5 activities that they will be completing. Each activity will be explained beforehand.*
- *The children will be given 5 minutes for each activity.*
- *The timer will go off and the children will move. Crossing off each activity they completed.*



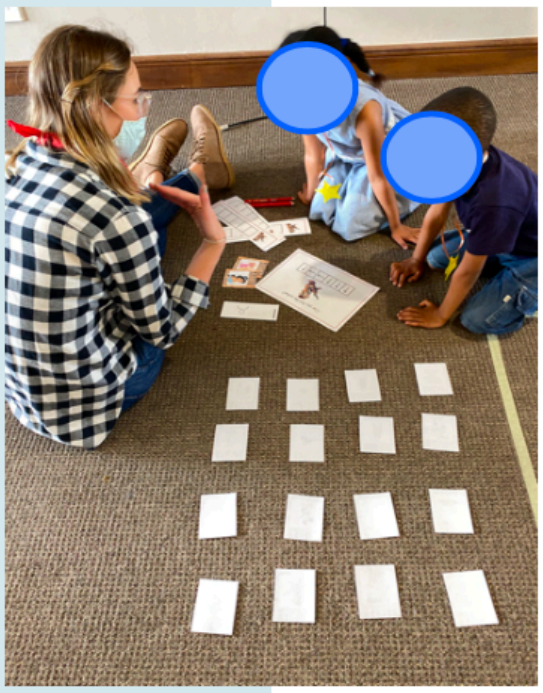
11

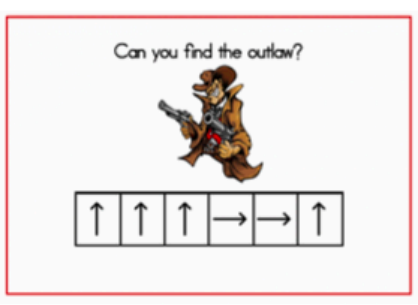
LESSON THREE:

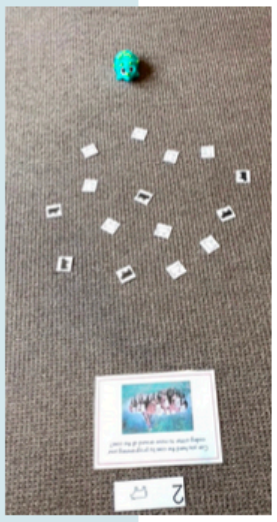
MAIN:

ACTIVITY 1:

- *A 4x4 grid is placed on the floor with "Most Wanted" picture cards. The cards are placed upside down. There is one outlaw in the pack of cards. The other cards are cartoon characters or pictures of the coding teachers. If the child picks up the outlaw card, they get a point. If they pick up a card that isn't the outlaw, they don't get a point.*
- *The children will work in pairs.*
- *They first will work together to follow the arrows that were given by the teacher to find the outlaw. Once the outlaw is found they will take turns. One will choose a new position to place the outlaw and draw arrows leading to the new position, while the other closes their eyes. Once the arrows are completed the one who closed their eyes will use the arrows to find the outlaw. The children will take turns placing the outlaw and finding him.*







ACTIVITY 2:

- *For this activity the children are encouraged to get the coding critter to go around all the "cattle".*
- *Cow cards are placed on the floor. The children have to program the coding critter to go around all the cow cards. The children complete this activity through trial and error.*

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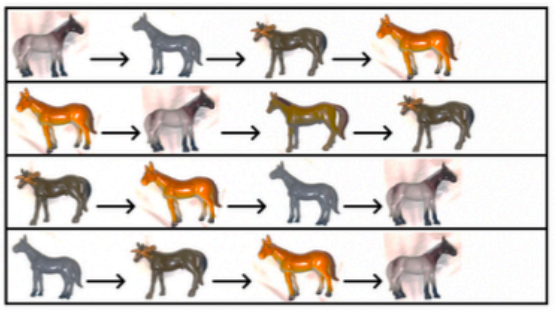
LESSON THREE:

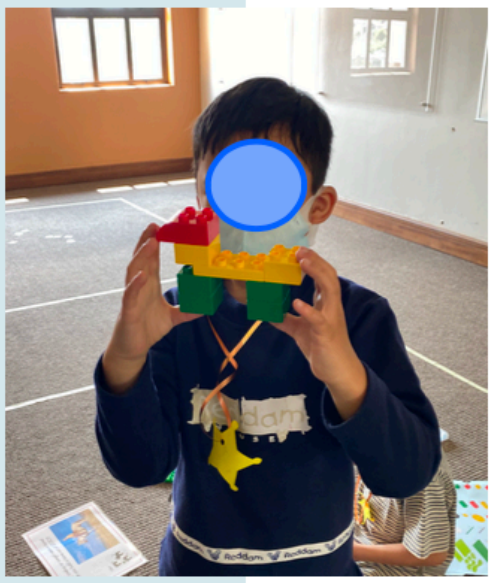
ACTIVITY 3:

- *For this activity the children are posed with the question to feed the horses.*
- *The children are given different strips that show the order of the different horses that need to be fed. · The children will use a coding critter to move between the different horses, to tap(feed) the horse.*
- *The children, working in pairs, must take turns and try get the coding critter to move to different horses and in the correct order, without knocking over the incorrect horse.*
- *Communication is encouraged between the children.*



ACTIVTY 4:

- *The teacher poses the children with the task… "Can you build a horse out of LEGO?"*
- *The children are encouraged to make their very own creations. The teacher did give the learners a hint.*
- *The teacher will ask open-ended questions regarding the creation they made and why it looks like a horse.*



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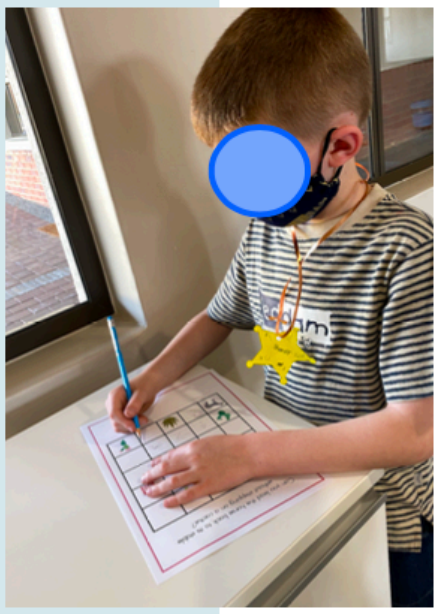
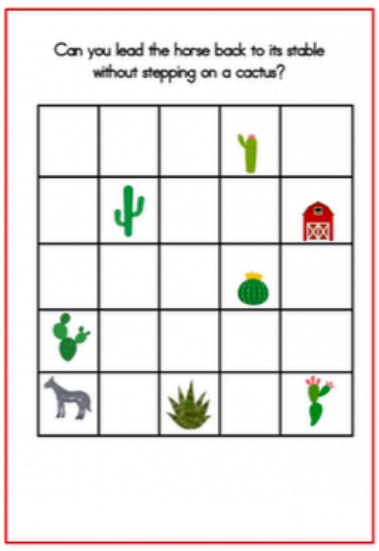
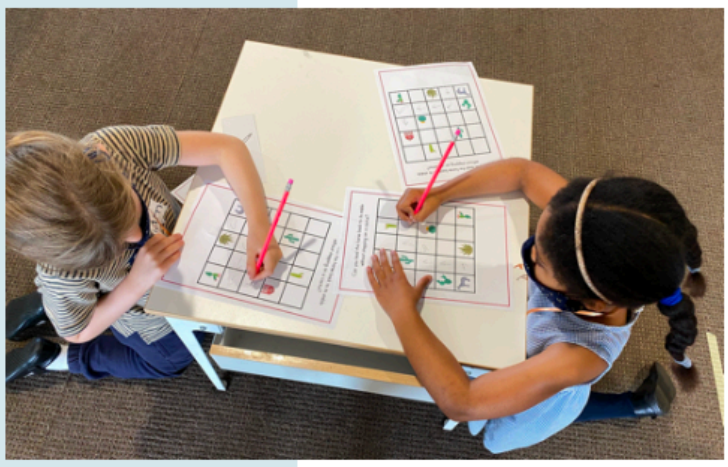
LESSON THREE:

CONCLUSION:

- *The children will each receive a grid. Using arrows, they must create a path to get the horse to the stable without walking into a cactus.*
- *There are multiple ways and the children are encouraged to come up with a unique and fun way.*
- *For this activity we encouraged the children to compare with one another, so that they can look at the different routes that were discovered.*







14

FEEDBACK FROM LESSON THREE:

SPECIFIC GUIDELINES WE DISCOVERED WHEN IMPLEMENTING THE LESSONS.

1. Another successful theme. The themes allow the children to develop those 21st Century skills as they communicate regarding the story or different scenarios, they are collaborating to solve a relevant problem. They are creative in regards to the theme and building something relevant to the theme. The children are encouraged to think critically of different scenarios in the correct context. Mainly seen in Activity 1.
2. The timer was effective as it allowed the children to complete all activities, however they didn't get time to play, therefore more time is needed.
3. The sheriff star (which encouraged the children to check-off the activities completed themselves, was effective for some children. however, the children wanted to focus more on the activity instead of checking them off.
4. During the conclusion the children interacted in a bigger group instead of in pairs and this got the children discussing interesting routes/scenarios and correcting each other with out the intervention of the teacher.
5. To ensure each skill (the 4 21st century skills) was met, there was a designated activity that focused mainly on that skill.This allowed for all the skills to have the opportunity to be developed.

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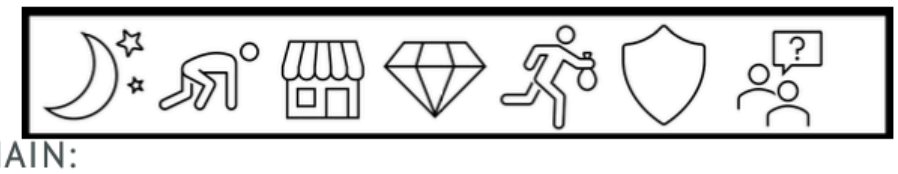
LESSON FOUR:

TOPIC: *Detectives*

INTRODUCTION:

- *A story was told about Peter the Cheater, the jewel thief.*
- *The teacher will give the children a slip with the images below. The children work in pairs to decode the pictures and tell the story the way they think it happened, using the pictures as clues.*
- *The teacher will then tell the learners to correct the order of events.*



MAIN:

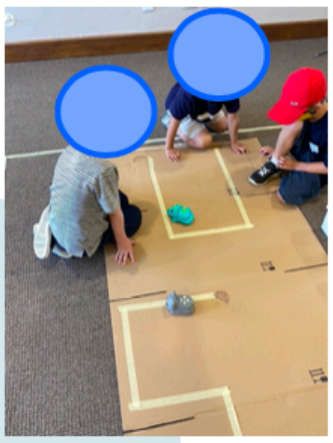
ACTIVITY 1:

- *The teacher introduces the activity with a story like introduction. "*

Some new evidence has been handed to the police to find Peter the cheater. Can you listen carefully? Once I have finished telling the story can you work in pairs to create a course that you think Peter the cheater took and discover where he is hiding now. Once stealing the jewel we think Peter the cheater went right to a restaurant, at the restaurant he ate a big juicy burger. We believe he then went to a hat shop and bought a new disguise. We found burger sauce all over the shop. We think Peter the Cheater then went and got an ice-cream before hiding out in a wooden cabin close by. Which cabin do you think he is hiding in? Can you draw the course that Peter the Cheater took?"

- *Using arrows, they must create a path to get to the correct cabin that Peter the Cheater is hiding in and they must also have the correct course. There are multiple ways and the children are encouraged to come up with a unique way. For this activity we encouraged the children to compare with one another and collaborate.*

16



LESSON FOUR:

ACTIVITY 2:

- *For this activity the children are encouraged to get the coding critter to travel along the lines of the different courses.*
- *The children must try catch the jewel thief. Using the coding critter, they must program the robot to follow along the lines to the thief.*
- *The children complete this activity through trial and error.*

ACTIVITY 3:

- *Once Peter the cheater was found he had 16 robbery bags. Using the arrows can you find the bag with the jewel inside?*
- *A 4x4 grid is placed on the floor with picture cards. The cards are placed upside down. There is one card that has a jewel on it. If the child picks up the jewel card, they get a point. If they pick up a card that doesn't have a jewel they don't get a point.*

ACTIVITY 4:

- *The teacher gives the children a task… "Can you build a key out of LEGO?"*
- *The children are encouraged to make their very own creations. This key will be used to lock Peter the Cheater away.The teacher will ask open-ended questions regarding the creation they made and how can it lock Peter the Cheater away*

CONCLUSION:

The children will each receive a grid. Using arrows, they must create a path that the robber took before stealing the jewels. The children must be creative in the path, yet they must consider all the clues. The children will compare their paths to each others.

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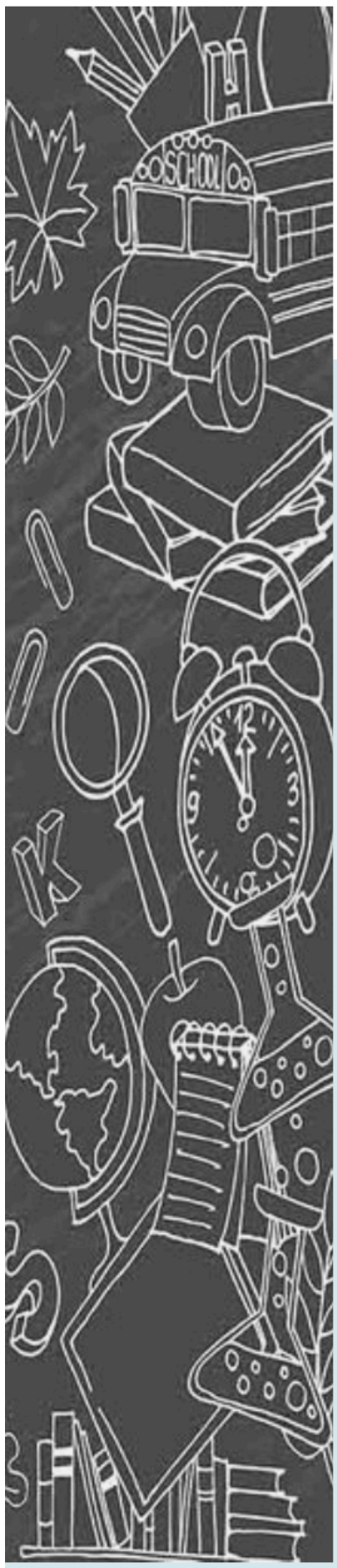

FEEDBACK FROM LESSON FOUR:

SPECIFIC GUIDELINES WE DISCOVERED WHEN IMPLEMENTING THE LESSONS.

1.Changing of the groups/ pairs allowed the children to communicate with someone else. This develops their communication and collaboration skills as the learners have to learn how to work together with someone else.
2. The story that the activities were based around got the learners excited as it progressed throughout the lesson. I strongly believe the theme aids in the development of 21st Century thinking skills, as not only does it encourage the learners to use their imagination but the children can add relevance to the activities and the task at hand.
3. The Lego activity was too easy. The children lost interest. Be aware of the level of difficulty when planning activities. Rather create an activity that the teacher can guide or extend depending on the learner.

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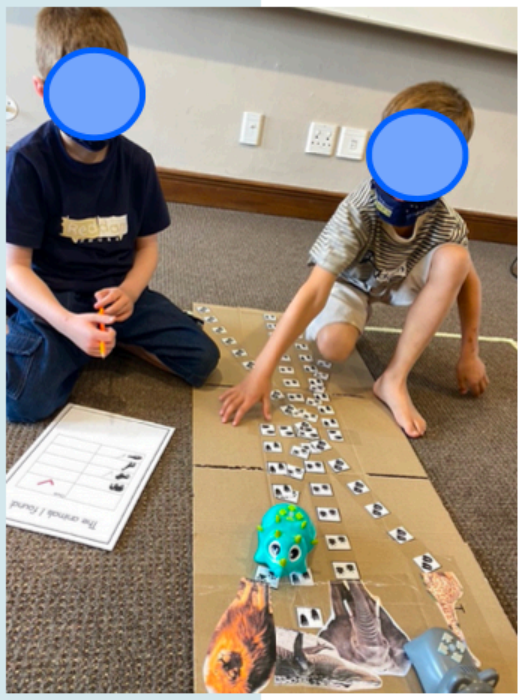
LESSON FIVE:

TOPIC: *Jungle Rangers*

INTRODUCTION:

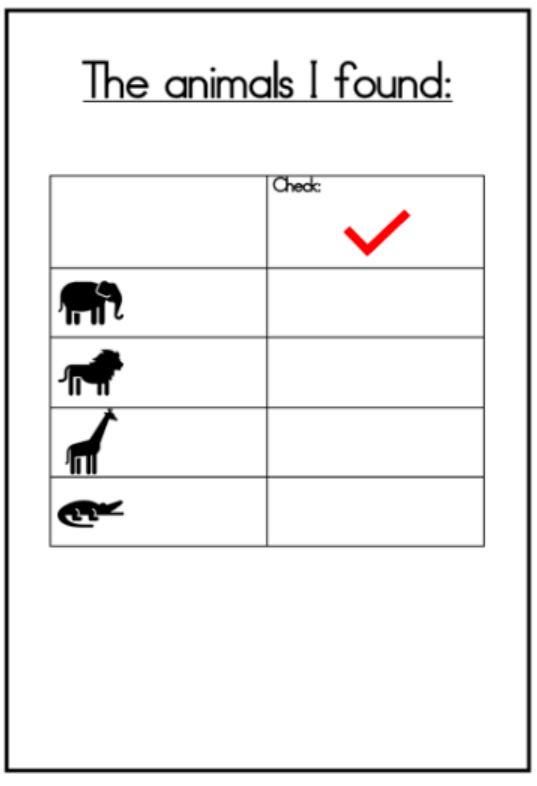
- The teacher introduced the theme and immediately started the different activities.



MAIN:

ACTIVITY 1:

- *For this activity the children use a coding critter to track different animals. Each child will receive a checklist of four animals. They must each program the coding critter to follow the animals tracks and to reach the animal. Once they have correctly coded the coding critter to reach the specific animal, the child can check the animal off the list.*



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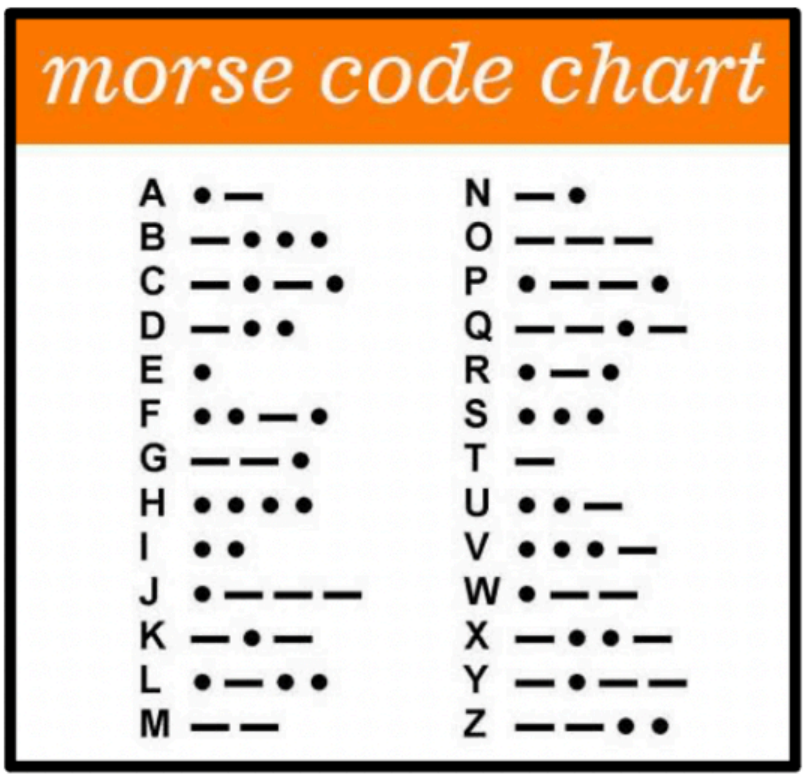
LESSON FIVE:

ACTIVITY 2:

- *Using a unique morse code the children beaded together a bracelet with their names on.*



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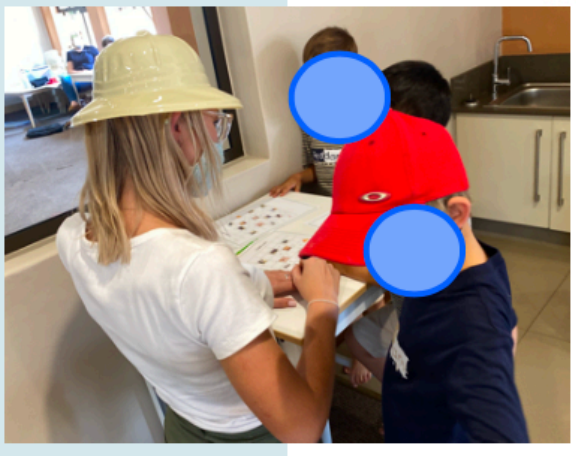
LESSON FIVE:

ACTIVITY 3:

- *The teacher introduces the activity with a story like introduction.*
- *Using arrows, the children must create a path to show the correct order of the animals they saw. The grid is similar to that of a game reserve map. The children must choose the correct path that was followed. There are multiple ways and the children are encouraged to come up with a unique and fun way. For this activity we encouraged the children to compare with one another and collaborate afterwards.*

Story:

We went on an exciting game drive and saw some fun and interesting animals. Can you map all the animals that you saw on our game drive in the correct order? Beware... don't get an animal that we didn't see. When we started our game drive we all climbed into our trusty game viewer vehicle. This will keep us safe, as well as let us see all the animals clearly. The first animal we saw was a giraffe. It was gracefully eating from the top of some very tall trees. Next we had to pass through a river and there we saw some crocodiles lying on the banks of the river. It looked like they were tanning. At the river we also saw the some cute eyes pop out from the top of the water. Wow! We saw some hippos! After we had passed through the river we stopped a pride of lions that were relaxing in the shade under a big umbrella tree. The last animal we saw was a very special animal that is endangered. We are trying our very best to look after these animals and protect them poachers who want their special horn. We saw the incredible rhino! After seeing all these incredible animals we decided it was time to go back to the camp site and relax in our cool tent.



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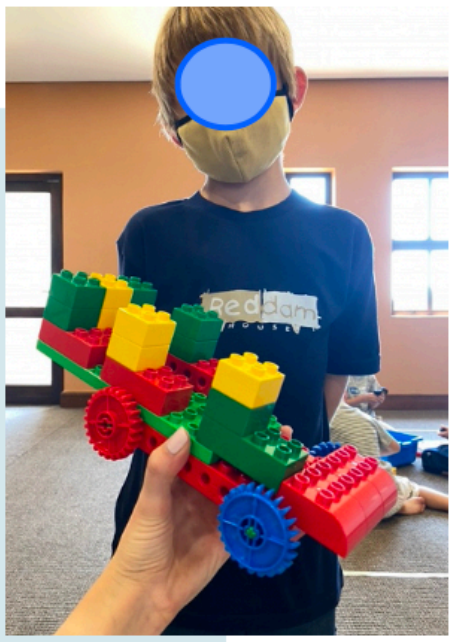
LESSON FIVE:



ACTIVITY 4:

- *The teacher gives the children a task… "Can you build a game-viewer out of LEGO?"*
- *The children are encouraged to make their very own creations.*
- *The children will be given images of game-viewers for inspiration in building their own creations.*
- *The teacher will ask open-ended questions regarding the creation and encourage the children to explain their creations in detail.*

CONCLUSION:

- *Story Line- Race To The Secret Lion Jewel*
- *The children will be posed with the challenge of getting to the jewel first. The children have to code their coding critter to reach the jewel first. If their coding critter stops before the jewel or if their coding critter doesn't end on top of the jewel, they must start again. The winner goes to the next round. The final winner receives a prize.*

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FEEDBACK FROM LESSON FIVE:

SPECIFIC GUIDELINES WE DISCOVERED WHEN IMPLEMENTING THE LESSONS.

1. Fewer activities, allowed the children to explore each activity to the fullest extent.
2. The conclusion of the lesson was a group work activity. The learners loved the competitive aspect of the activity. It got the learners excited and thinking under time pressure.
3. The activities required very little teacher intervention and allowed the teacher to mainly facilitate and ask open-ended questions. This encouraged the children to think for themselves in a creative and critical way.
4. The different resources/apparatus used at each activity, provided a variety to the activities which encouraged the children to try each station.