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Whole Brain® thinking action-research in a coding and robotics curriculum for Grade 4

by

Soené Botha

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Declaration and Ethics Statement

I declare that the thesis I submit for the degree Philosophiae Doctor in Computer Integrated Education at the University of Pretoria is my work and has not previously been submitted by me for a degree at this or any other tertiary institution.

The author, whose name appears on this thesis's title page, has obtained the applicable research ethics approval for the research described in this work. The author declares that they have observed the ethical standards required in terms of the University of Pretoria's Code of ethics for researchers and the Policy guidelines for responsible research.

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August 2024

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August 2024

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Abstract

This study addresses the challenges faced by a private school in implementing the Department of Basic Education's (DBE) coding and robotics curriculum for Grade 4 learners. The standard curriculum was found to be inadequate in meeting the specific needs of the school's educational environment and diverse learner profiles. To bridge this gap, the research aimed to design, implement, and continually refine a Whole Brain® coding and robotics curriculum tailored to these specific needs.

The research question guiding this study was: How can action research principles be utilised to monitor and iteratively improve the design of a Whole Brain® coding and robotics curriculum for Grade 4 learners? This investigation employed a qualitative, action research methodology, combining iterative design, real-time classroom implementation, and reflective analysis. The Whole Brain® model, which integrates cognitive diversity by addressing different thinking preferences, served as the theoretical framework for the curriculum development. This framework was implemented through targeted instructional strategies and activities designed to engage all learners, regardless of their cognitive preferences.

The study's findings revealed significant improvements in learner engagement, mastery of coding concepts, and the development of 21st century skills such as critical thinking, communication, problem-solving, and collaboration. Data were collected through classroom observations, learner assessments, and reflective journals, which were analysed to refine the curriculum continuously. The iterative process allowed for adjustments based on real-time feedback, ensuring that the curriculum remained relevant and effective.

The integration of Whole Brain® principles not only enhanced inclusivity by catering to diverse cognitive styles but also fostered a balanced learning environment that promoted both creativity and analytical thinking. This research contributes a novel approach to curriculum development in technology education, demonstrating that action research, combined with a cognitive diversity framework, can effectively bridge the gap between theoretical research and practical teaching. The implications of this study extend beyond the local context, offering a scalable model for other educational settings facing similar challenges.

Key words: 21st Century skills; Action research; Coding; Curriculum development; Robotics; Whole Brain® thinking

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To whom it may concern,

I do hereby confirm that I have proofread the dissertation entitled:

Whole Brain® thinking action-research in a coding and robotics curriculum for Grade 4

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August 2024

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List of Abbreviations

4IR	Fourth Industrial Revolution
AI	Artificial Intelligence
AR	Action Research
CAPS	Curriculum Assessment Policy Statement
DBE	Department of Basic Education
HBDI®	Herrmann Brain Dominance Instrument HBDI®
ICT	Information Communication Technology
IOT	Internet of Things
NCS	National Curriculum Statement
PWC	PricewaterhouseCoopers
RESA	Robotics Education South Africa
SA	South Africa
STEAM	Science, Technology, Engineering, Arts and Mathematics
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organisation
VR	Virtual Reality

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1. CHAPTER 1: AMBIENCE OF THE STUDY

1.1 Setting the tone

Albert Einstein (1955) said that the key is to never stop asking questions as curiosity has its own purpose in life. In light of this statement, this chapter sets the tone for the study by introducing an innovative research idea for developing a Whole Brain® Grade 4 coding and robotics curriculum.

Throughout the past few centuries, the world has transitioned through multiple industrial revolutions, which have introduced many new ways to execute tasks in our daily lives (Khoza, 2020). In 2016, the Fourth Industrial Revolution (4IR) started to evolve (Didier, 2024; Khoza, 2020; Mykhailychenko, 2019). According to Ally and Wark (2020), the 4IR is a term used to describe the ongoing transformation of the global economy and society through the integration of advanced digital technologies. They further explain that advanced digital technologies are a category of technologies that increase performance and efficiency across a range of sectors by using computing power, connectivity, and automation such as artificial intelligence (AI), robotics, and the Internet of Things (IoT).

AI refers to technologies that allow robots and programs to carry out operations that commonly require human intelligence, such as speech recognition, visual perception, decision making, and natural language processing (Moore, 2019). According to Tzagkaraki et al. (2021) designing, creating, and using robots are all part of robotics. They explain that robots are machines that may be programmed to complete a variety of tasks either on their own or with human assistance. Madakam et al. (2015) explain that the IoT is a network of interconnected devices that can exchange and collect data. They further state that these devices might range from sensors and cell phones to automobiles and home appliances. Ally and Wark (2020) and Nalubega and Uwizeyimana (2019) explain that one of the key features of the 4IR is the growing use of automation and advanced robotics in various industries. According to them, this is leading to a significant shift in the nature of work, with many traditional jobs being replaced by advanced digital technologies. While this trend is likely to increase productivity and efficiency, it also poses a challenge for workers who will need to acquire new competencies and adapt to changing job requirements (Ally & Wark, 2020; Cook, 2021).

For learners to adapt to the technological advancements, they undoubtedly need to develop 21st century competencies as scholars such as Reaves (2019), Du Toit-Brits and Blignaut (2019), Verster et al. (2018), and Barbazzeni (2021) suggest. Among a variety of competencies, Amri et al. (2019), Lathifah et al. (2019), and Budhai and Taddei (2015) highlight four essential competencies known as the 4Cs of the 21st century. These abilities include, but are not limited to, communication, collaboration, critical thinking, and creativity (these are discussed in more depth in Chapter 2). Lathifah et al. (2019) are of the view that educational robotics can be considered one way of offering learners the opportunity to master competencies needed for this century and for the future. As a result of the need for these competencies, coding and robotics education are increasingly becoming an integral part of education (Csilla et al., 2022; Kanbul & Uzunboylu, 2017).

In line with the opportunities that robotics offers, the South African Department of Basic Education (DBE) developed a digital competencies curriculum, to enhance the current Curriculum and Assessment Policy Statement (CAPS) (Department of Basic Education, 2021d; Van Laar et al., 2017). CAPS is an educational framework that offers direction and structure for the curriculum and assessment in South African schools (DBE, 2021b). CAPS was presented as a thorough curriculum reform program to raise the standard of education in South Africa and match the curriculum to the requirements and aims of the nation's educational system (DBE, 2021b). In short, it is a single, comprehensive, and condensed policy document.

The proposed amendments to the CAPS document, encompassing coding and robotics for Grades R – 9, were officially published in March 2021, as reported by the Department of Basic Education (DBE, 2021a, d). Commencing in 2021, the piloting period was anticipated to conclude in 2023. However, the Department has announced the annual performance plan for 2022 and 2023, as highlighted by Adewusi (2020) and Mathopo (2022). This plan delineates the complete implementation of the programme for Grade R – Grade 3 and Grade 7 during the 2023 academic year. Looking ahead, the 2024 academic year is slated for the comprehensive rollout of the curriculum for learners in Grades 4 – 6 and Grade 8, as outlined by Liebenberg (2023). Subsequently, Liebenberg (2023) also indicates that the 9th graders are expected to follow suit in the academic year of 2025. These developments underscore the phased and strategic approach taken by education authorities in integrating coding and robotics across various grade levels.

The design and development of a Whole Brain® coding and robotics curriculum for fourth-Grade learners are the focus of this study. This curriculum was designed using backward design principles, which entails starting with formulating the desired meaningful learning competencies, working backward to choose the learning experience tasks required to achieve the desired meaningful learning experiences, and then choosing the assessment opportunities aligned with the goals of the learning experiences (Emory, 2014; Knowledge Base, 2021; Wiggins & McTighe, 2005). To create learning opportunities that would allow learners to self-equip with the necessary competencies and knowledge, educators must design effective and engaging curricula that cater to different thinking preferences as Herrmann (1995) suggests in his seminal work.

It is common to find that reference is made to the construct 'thinking preferences' by some authors (Herrmann, 1999). Herrmann-Nehdi (2010) explains that a holistic framework that can improve the efficiency of teaching and learning is the Whole Brain® learning approach (discussed in Chapter 2). The study employed the action research (AR) process, which is a reflective and iterative method for professional development (Cabaroglu, 2014; McAteer, 2013; McNiff & Whitehead, 2001), to enhance the comprehensive framework. The utilisation of this methodology facilitated the ongoing assessment of the curriculum's efficacy during its various phases, including design, development, and implementation. By employing a systematic approach involving the stages of planning, action, observation, and reflection, I was able to acquire significant knowledge and implement incremental enhancements to the curriculum, thereby guaranteeing its congruence with the intended educational objectives and the requirements of the students.

This study details how the Whole Brain® coding and robotics curriculum was created and used in a Grade 4 classroom. I discussed the outcomes of the action research process, including educator and learner input, as well as how I ensured that the programme creates opportunities for learners to achieve the learning outcomes.

The overall goal of the research was to offer views into the creation of successful and innovative robotics and coding programmes that accommodate various thinking preferences.

1.1.1 Setting the scene

The research setting was an English-medium independent school located in Pretoria, South Africa. This school is a small, combined pre-primary (below the age of 6), primary (Grades 1 – 7) and high school (Grades 8 – 12), which provides various academic, sports, and cultural programmes. One of the academic foci is coding and robotics. Coding and robotics were taught as a stand-alone subject for the first time in 2023 in this school. Learning opportunities are offered once a week for an hour during normal teaching time.

After being asked by the school to present coding and robotics as a co-curricular in 2022 and as a standalone subject in 2023, I studied the proposed coding and robotics curriculum designed by the Department of Basic Education (2021a). The school realised that their learners did not have the basic competencies to complete the study areas as described in this curriculum. Recognising the need to address both the current competencies of the learners and the competencies they needed to develop, I embarked on developing a coding and robotics curriculum. Employing a synchronist model (Randewijk & Du Toit, 2022), I not only offered this curriculum but also continuously refined and developed it in tandem with its implementation. This curriculum in the making allowed the school to experiment with different learning and assessment opportunities. Experimenting with ideas is typical of action research as McNiff and Whitehead (2001), McNiff (2016) and Clark et al. (2020) advocate.

The design and development of the curriculum took place in the ICT classroom. This classroom is equipped with 14 Samsung tablets, a whiteboard, an overhead projector, and speakers. The tablets have Internet access and have the LEGO® Spike Prime™ application installed. There are eleven LEGO® Spike Prime™ coding and robotic sets. An example of such a set is represented by means of Image 1. LEGO® Spike Prime™ is an educational tool designed to facilitate the learning of learners about robotics, engineering, and programming (LEGO® Education, 2022). It is a hands-on learning system that uses LEGO® Technic and System bricks, sensors, and a programmable hub to enable learners to build and program their own robots.

As shown in Image 1, the set includes over 500 LEGO® Technic and System components in a variety of shapes, sizes, and colours, a programmable hub which is a small, portable, programmable device that uses rechargeable batteries to operate a number of sensors and motors, one large and two small motors that can be used to power a variety of LEGO® models, a colour sensor, which can distinguish between colours and levels of light, a force sensor which is capable of detecting vibrations and forces or pressure, a large hub which displays animations, graphics and text and other sensors such as a gyro sensor, a distance sensor, and a touch sensor. I am responsible for offering the curriculum. I use my personal laptop and tablet to facilitate learning.

Image 1

LEGO® Spike Prime™ robotic set (LEGO® Education, 2022)

1.1.2 Contribution to the educational field

A practical, theoretical, and methodological contribution is made to the educational profession by developing the Whole Brain® action research-driven curriculum. This also served as the foundation for an action research-driven Whole Brain® coding and robotics curriculum with significant practical, theoretical, and methodological contributions to the educational field. At a practical level, it can provide learners with opportunities for experiential learning that engages both hemispheres of the brain and promotes a deeper comprehension and memory of coding principles (Ibrahim et al., 2020; Potgieter, 1999). By offering learners the opportunity to practise problem-solving and critical thinking competencies, it can theoretically advance the theories of constructivism (Kivunja, 2014; Topolovčan & Matijević, 2017) and inquiry-based learning (Duran & Dökme, 2016; Wale & Bishaw, 2020). In terms of methodology, it can offer a framework for creating and assessing new curricula that are based on sound research principles, such as well-defined research questions, suitable research methodologies, and rigorous data analysis procedures. By encouraging research-driven and learner-centred approaches to curriculum creation and implementation, a Whole Brain® action research-driven curriculum development process and curriculum has the potential to improve the quality of education.

I aimed to contribute to two distinct fields of scholarship: the scholarship of action research and the scholarship of curriculum development as an independent field of specialisation. I do this by presenting an innovative Whole Brain® action research-driven curriculum development model.

1.2 Rationale

The ongoing technological transformation continuously confronts the South African education system (Magagula & Awodiji, 2024, Du Toit-Brits & Blignaut, 2019; Kayembe & Nel, 2019). This influences the acquisition of competencies and learners' need to ensure adaption within the 4IR. The South African education system needs to create opportunities for learners to develop the necessary competencies to be employable (Veldman et al., 2021) and contribute meaningfully to society and the economy (Amri et al., 2019). According to the objectives stated in the National Curriculum Statement (NCS) of South Africa (DBE, 2011) the government has identified the need for progressive change to the education system by giving learners the opportunity to develop 21st century competencies.

In line with the changing world, South Africa is expanding the current CAPS curriculum to include more technology subjects, such as digital technologies and coding and robotics (South African Government, 2019), as well as technical occupational disciplines such as electrical, civil and mechanical technologies (SA

News, 2022). I focused on coding and robotics. Coding and robotics allow learners to master valuable and relevant competencies needed in the 4IR and the 21st century – to enter the workforce as well-rounded employees or to pursue further studies.

I studied the proposed coding and robotics curriculum and the final coding and robotics curriculum designed by the Department of Basic Education (2021d; 2024). Firstly, I noticed that this curriculum does not address the basic competencies needed to complete a coding and robotics program. Prinsloo (2024) also explains that the proposed curriculum and content for coding and robotics acknowledges that the implementation of the subject require a substantial number of resources, however, the curriculum fails to mention the importance of developing essential foundational skills that serve as pre-knowledge for learners. The Grade 4 learners initially did not have the basic competencies to complete physical coding learning tasks within the first few weeks. They also did not have basic knowledge of robot building such as mechanical and electrical components to physically build a robot within the first few weeks.

Secondly, the school did not have the required infrastructure or coding and robotics resources to present the curriculum as required by the Department of Basic Education. The Department of Basic Education (2024) requires that each learner have a coding and robotics kit and each kit should have a microcontroller, basic electrical components, basic temperature, humidity, light and motion sensor modules, basic mechanical components, and basic tools. The basic electrical components include switches, batteries, wires, breadboards, motors, and lightbulbs. The basic mechanical components refer to wheels, axles, pulleys, linkages, gears, fans, and fasteners. Basic tools include pliers, string, glue, scissors, project knives, rulers, insulation tape and screw drivers. The school uses eleven LEGO® Spike Prime™ coding and robotic sets, of which an example can be seen in Image 1. This kit does not have all the required components, such as a microcontroller and basic electrical components. There also is no access to a basic tool kit.

Lastly, the Department of Basic Education (2024) requires the Grade 4 learners to attend coding and robotics for two hours a week for four terms. The school's programme runs an hour a week for three terms only. Therefore, the school needed a specifically tailored curriculum, aligned with that of the Department of Basic Education.

1.3 Innovative research idea

During the course of the study, I developed an action research-driven curriculum design model (as illustrated in Appendix B) to aid in the design of the Whole Brain® coding and robotics curriculum in question. This curriculum design model reflects an iterative process, where I developed a curriculum plan based on the needs of the school, and the needs of the learner. A curriculum plan is a detailed document that outlines the structure, content, and organisation of a specific educational programme or course (Nicholls & Nicholls, 2018). The process involved a "working backwards" strategy, beginning with the formulation of desired learning outcomes. Next, the necessary content to facilitate these learning experiences was selected, followed by the identification of assessment opportunities to determine the attainment of these outcomes.

The curriculum developed was designed based on the identified learner needs and competencies. Principles of learning theories that are considered to promote innovative means of facilitating learning that can contribute to transforming teaching practice were employed. (See learning theories indicated under the section on 'construct frame'.) Competencies identified gave a clear indication of the learning component of the curriculum and as to which focus areas – content knowledge and practical competencies – should be included in the curriculum. Apart from the following essential focus areas that form the crux of the nature of the subject, other focus areas may emerge:

a) Algorithms and coding competencies
b) Robotic competencies
c) Application competencies

In Grade 4, algorithms and coding are developed using block-based coding programs. Block-based coding refers to coding that is visually simple but still likes traditional coding (Codejig, 2022). These programs consist of blocks with basic instructions that a learner must connect to form an algorithm (Codejig, 2022).

A competency-based curriculum was envisaged. The construct 'competency-based' highlights the fact that a clear purpose statement was formulated. Such a purpose statement should include the specific aim of the programme. Aspects that complemented a competency-based curriculum, innovation and transformative teaching practice were included.

Phase1: Needs analysis

a) Learner profile
b) Environmental and learning conditions
c) 21st century competencies

Phase 2: Backward design

With the backward design, I illustrated the alignment between the competencies, appropriate assessment opportunities and learning opportunities and facilitating learning. Each learning opportunity began by outlining the specific competencies that learners were expected to achieve. This was followed by a description of the learning activities and assessments that comprised the learning opportunities. Afterward, learners were presented with a challenge in the form of a task that was part of a range of authentic assessment opportunities. These tasks aimed to evaluate whether learners developed the desired competencies. It was envisaged, depending on the needs analysis, that these learning opportunities were presented on the beginner level of coding and robotics.

Phase 3: Action research

This phase consists of different cycles and each cycle consists of the action research steps I have selected, namely planning, action, observation and reflection. Each cycle informed the next cycle. The action research process also represents the curriculum development process.

1.4 Action research questions

To guide the action research-driven curriculum development process, the following questions were formulated:

1.4.1 Primary research question

In light of the dynamic landscape of educational technology and the imperative to provide learners with relevant and effective learning experiences, this research seeks to address the following primary research question:

How can I use principles of action research to self-monitor the design and continual development of a Whole Brain® coding and robotics curriculum for Grade 4 learners?

1.4.2 Secondary research questions

To further explore the nuances of implementing an action research-driven self-monitoring process for curriculum design and development, this study delves into the following secondary research questions:

1. What pre-existing conditions need to be in place to implement an action research-driven Whole Brain® coding and robotics curriculum?
2. What will an action research-driven Whole Brain® coding and robotics curriculum entail?
3. How did the Whole Brain® approach enhance the quality of the coding and robotics curriculum for Grade 4 learners?
4. To what extent did the backward design approach contribute to the development of an effective and engaging coding and robotics curriculum for Grade 4 learners?

1.5 Construct clarification

It is common to find the words 'concept clarification' being used in research studies. As the epistemological stance taken by me is constructivism, I chose to use the wording 'construct clarification'. This is advocated by scholars such as Du Toit (2017), Smit (2020) and De Boer et al. (2013). This means of clarification is an essential procedure that aids readers in comprehending what is meant by the new meaning constructed by me – often referred to as new meaning-making (Krauss, 2005). Insights that I have gained through the course of conducting the research project are shared next.

Action research (AR)

According to Maree (2016) and Elliot (as cited in Feldman et al., 2018) action research (AR) is a research method used to transform practice by finding solutions to existing problems or challenges, while contributing to an existing field of knowledge. In my study, I used action research as the primary method to develop and implement an innovative curriculum in coding and robotics. I employed interviews and photo evidence as specific methods to gather data and insights. These methods align with the goals of action research, which include transforming practice by addressing existing challenges and contributing to the field's knowledge base. By using these methods, I am seeking solutions to problems while also generating new knowledge that can benefit both my practice and the broader educational community.

Curriculum

Booyse and Du Plessis (2018) define a curriculum as a plan for learning, which includes all plans to guide learning to achieve the specified goals. Dey (2016) explains that it is a written document that is used as a part of formal instruction and has certain pre-set objectives. I view a curriculum as a dynamic framework that not only provides guidelines but also serves as a roadmap. This roadmap outlines the learning journey for both educators and learners. A well-crafted curriculum integrates various components such as learning opportunities, teaching opportunities, assessment methods, and resources, all aimed at achieving predetermined educational goals and learner competencies. It is a tool that shapes the educational experience, reflecting the values, beliefs, and goals of a learning community.

Curriculum development

Booyse and Du Plessis (2018) is of the view that curriculum development refers to a process of curriculum improvement or innovation. Marzooghi (2016) states that the preparation, implementation, and evaluation of an existing curriculum can be viewed as curriculum development. In my opinion, curriculum development is the process of creating or revising a curriculum to meet the needs of learners, educators, and the educational institution or system. It involves a systematic approach to designing a curriculum that aligns with educational goals, standards, and principles. Curriculum development typically includes identifying learning objectives, selecting appropriate content and instructional methods, designing assessment strategies, and organising the curriculum into a coherent plan for implementation. I rather use a more contemporary construct such as ‘means of facilitating learning’ as a design principle. This process is often collaborative, involving input from various stakeholders such as educators, administrators, students, and community members. The goal of curriculum development is to create a curriculum that is effective, relevant, and engaging, ultimately enhancing the learning experience for students.

Coding and robotics

Educational robotics refers to the discipline of introducing learners to coding and robotics (DBE, 2021c), intending to engage learners in practising problem-solving competencies by using programming competencies (Van Laar et al., 2020; Yasar, 2021). In this study, coding and robotics refer to an environment where opportunities are created for learners to develop relevant 21st century competencies.

Industrial revolution

An industrial revolution, according to Daemmrich (2017), is characterised by technical advancements that transform conventional ways of doing things. An industrial revolution, according to Kayembe and Nel (2019), is a large technological progress, change, or transition that has an impact on society. According to Daemmrich (2017), there have been three industrial revolutions throughout history, and the fourth one has already begun.

Fourth Industrial Revolution (4IR)

We are in the era of the fourth industrial revolution, often known as Industry 4.0, claim Daemmrich (2017) and Schwab (2017). This revolution is defined by a number of technologies that blur the lines between the physical, digital, and biological realms (Kayembe & Nel, 2019; Schwab, 2017). The Department of Basic Education (DBE) (2021a) defines the 4IR as technological developments that combine the physical, digital, and biological spheres to impact the work, education, services, and leisure sectors. In this study, the 4IR refers to the industrial revolution, where technology is developing tremendously and especially influencing education.

21st Century competencies

21st century competencies refer to a group of competencies that are deemed essential for achieving success in the modern world. According to Amri et al. (2019) and Lathifah et al. (2019), the acquisition of competencies such as collaboration, communication, critical thinking, and creativity is imperative for effectively navigating the intricate challenges of the 21st century. The term "21st century competencies" in this study refers specifically to the abilities needed to adjust to the swift transformations caused by the Fourth Industrial Revolution (4IR). The inclusion of Whole Brain® thinking competencies, as argued in section 2.2.2, is imperative. These competencies underscore the amalgamation of logical and analytical thinking (left brain) with creative and innovative thinking (right brain).

Backward design

Backward design refers to an instructional design process that starts with the end in mind (Wiggins & McTighe, 2005). The instructional designers will start with the outcomes or desired competencies. After setting the outcomes, they will develop the assessment opportunities or evidence and then, lastly, the learning experiences and instruction (Wiggins & McTighe, 2005). The learning experiences and teaching experiences include all teaching and learning resources. This approach ensures that the instructional design is purposeful and aligned with the intended learning competencies, ultimately leading to more effective teaching and learning experiences.

1.6 Whole Brain® action research

The model of curriculum development was based on three different models, namely Whole Brain® thinking, action research, and the backward design model.

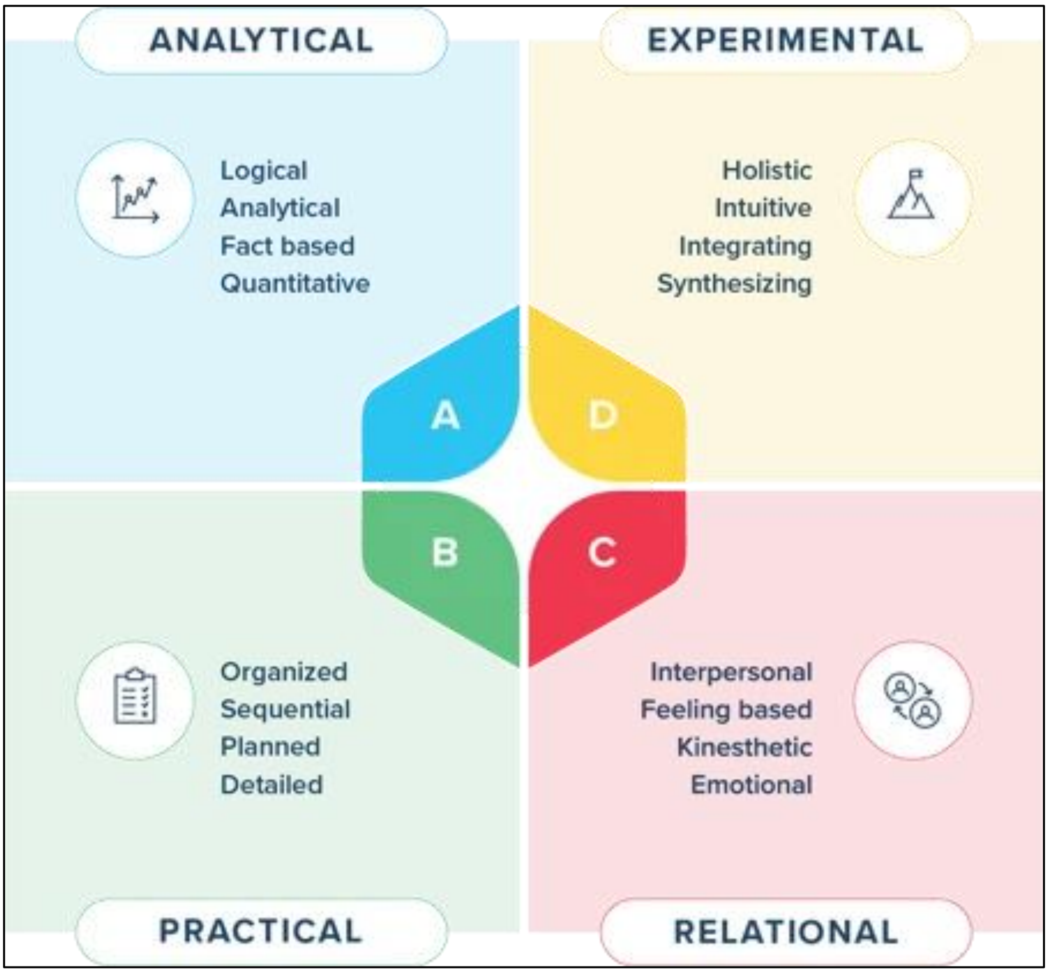
1.6.1 Understanding the holistic nature of Whole Brain® thinking

In crafting an innovative curriculum for Grade 4 learners that integrates coding and robotics, this study adopts an action research-driven model, strategically guided by the principles of Whole Brain® thinking. Whole Brain® thinking, as developed by Ned Herrmann, emphasises the utilisation of diverse cognitive processes, acknowledging the varied strengths and preferences learners exhibit (Herrmann, 1995). In the upcoming section, I will delve into the holistic nature of Whole Brain® thinking.

The construct of Whole Brain® thinking suggests that individuals have preferences for modes of thinking in four quadrants: A, B, C, and D. These quadrants correspond to analytical, practical, relational, and experimental thinking, respectively, as illustrated in Figure 1. My curriculum development model acknowledges the imperative of addressing all of these cognitive domains, promoting comprehensive learning opportunities.

Figure 1

Basic Whole Brain® thinking model (Herrmann Global LLC, 2017)



Within the realm of curriculum development, it is crucial to recognise and adapt to these varied thinking preferences. Individuals classified as analytical thinkers (quadrant A) demonstrate exceptional abilities in tasks that involve logical reasoning and problem-solving (Herrmann-Nehdi, 2010; Herrmann Global LLC, 2016, 2022; Herrmann, 1999). Practical thinkers (quadrant B) excel in activities that are hands-on and applied in nature (Herrmann-Nehdi, 2010; Herrmann Global LLC, 2016, 2022; Herrmann, 1999). Individuals who think in terms of relationships (quadrant C) may derive benefit from engaging in collaborative and interpersonal learning opportunities, while those who think experimentally (quadrant D) may actively pursue creative and innovative methods for comprehending constructs (Herrmann-Nehdi, 2010; Herrmann Global LLC, 2016, 2022; Herrmann, 1999).

Studies suggest that customising the teaching method to match individual thinking preferences can improve the achievement of overall learning outcomes (Dlamini, 2020; Herrmann-Nehdi, 2010; Herrmann Global LLC, 2022; Le Roux, 2011; Oosthuizen, 2007). The integration of Whole Brain® thinking into curriculum design has been acknowledged for its capacity to effectively engage learners by accommodating their preferred thinking styles (Herrmann Global LLC, 2022). My curriculum development model strategically incorporates learning opportunities that target each quadrant, aiming for a comprehensive and inclusive learning experience for Grade 4 learners.

My curriculum development model aims to surpass the constraints of a uniform approach by acknowledging the comprehensive nature of Whole Brain® thinking. Research has shown that taking cognitive diversity into account in educational environments has a beneficial effect (Dlamini, 2020; Herrmann-Nehdi, 2010; Herrmann Global LLC, 2022; Le Roux, 2011; Oosthuizen, 2007). This underscores the importance of using flexible methods of facilitating learning (Randewijk & Du Toit, 2022). Addressing all four quadrants adheres to the principles of differentiated facilitating learning, fostering a comprehensive learning environment that caters to diverse thinking preferences (Herrmann Global LLC, 2022).

In conclusion, the integration of Whole Brain® thinking into curriculum design offers a flexible and effective way to engage learners by accommodating their preferred thinking styles. By addressing all four quadrants, the curriculum development model adheres to the principles of differentiated learning, creating a learning environment that caters to diverse thinking preferences and fosters comprehensive learning.

1.6.2 Backward design model

This curriculum design model incorporates the foundational principles of backward design, a theory initially introduced by R. W. Tyler in 1949 and further refined by educational theorists Wiggins and McTighe (2005). Backward design represents a strategic approach to curriculum development, illustrating an instructional design process that commences with the end goal in mind. This methodical approach prioritises the identification of desired learning outcomes or competencies as the starting point (Buehl, 2000; Knowledge Base, 2021). By establishing clear and measurable outcomes from the outset, educators can then proceed to develop assessment opportunities or evidence that effectively evaluate the attainment of these outcomes (Tyler, 1949).

Figure 2

Backward design model (adopted from Wiggins & McTighe, 2005)

Subsequently, the focus shifts towards the development of learning experiences and instructional strategies. This involves the careful selection and design of activities, resources, and materials that will best facilitate the achievement of the desired competencies (Bhuttah et al., 2019; Tyler, 1949). By placing the design of learning opportunities at the end of the process, educators can ensure that the learning experiences are purposeful and directly aligned with the intended competencies (Emory, 2014; Knowledge Base, 2021).

In my opinion, this curriculum design model emphasises a departure from the traditional term "instructional design" in favour of a more contemporary construct known as "means of facilitating learning." This terminology shift signifies a broader and more inclusive approach to curriculum development. It encompasses not only the design of instructional materials but also the intentional design of learning outcomes, assessment opportunities, and the learning environment. This comprehensive approach is aimed at optimising the learning experience for students, enabling them to develop the desired knowledge and competencies effectively.

By adopting this approach, the design of the curriculum becomes purposeful and aligned with the intended learning goals. This alignment ensures that the teaching and learning experiences are more effective, ultimately leading to improved learning outcomes for students.

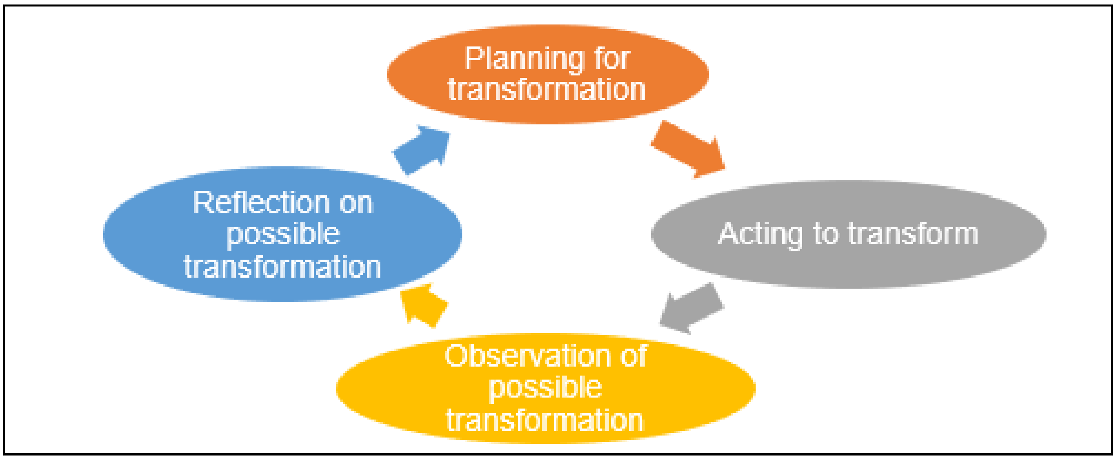
1.6.3 Asset-based approach to action research

The curriculum development included principles of action research. The methodology of action research has undergone evolution over time, becoming a dynamic and participatory approach. The asset-based approach, advocated by scholars such as McAteer (2013), McNiff (2016), and the collaborative efforts of McNiff and Whitehead (2001), is a prominent methodology in this particular field. In contrast to deficit-approach, the asset-based approach redirects attention towards assets, strengths, and resources (McNiff, 2013; McNiff, 2016).

McAteer (2013) and Clark et al. (2020) explain that action research consists of different spirals consisting of different cycles. Each cycle consists of four steps. These steps encompass planning, taking action, observation, and reflection (McAteer, 2013; McNiff, 2016; McNiff & Whitehead, 2001). During the planning step, researchers explore the context to determine problems and create an action plan (McAteer, 2013). Since I am using an asset-based approach, my focus is not on identifying problems but on understanding the assets and strengths available, as represented in the action research cycles, which can be seen in Figure 3. During the planning step, I explored the context to determine the assets and strengths, also referred to as initiatives that can be leveraged to bring transformation and create a plan for transformation based on this. Implementation or action involves carrying out the plan (Kemmis et al., 2019). Here I put my transformation plan into action. Observation entails the ongoing collection of data through various methods and making observations (McNiff, 2016). During the observation of the transformation, I used various methods as discussed in Chapter 3 to collect data on the transformation. Reflection involves engaging in reflective practices and interacting with relevant stakeholders to assess the outcomes and influences of the interventions (McNiff & Whitehead, 2001). During this step I reflected on the initiatives implemented to modify the plan for transformation and refine the interventions.

Figure 3

Basic action research model (adapted from McNiff, 2016)



1.6.4 Action research model and the principles of Whole Brain® thinking

This section delves into the symbiotic relationship between action research and the principles of Whole Brain® thinking, serving as the foundational framework for the development of a coding and robotics curriculum tailored for Grade 4 learners.

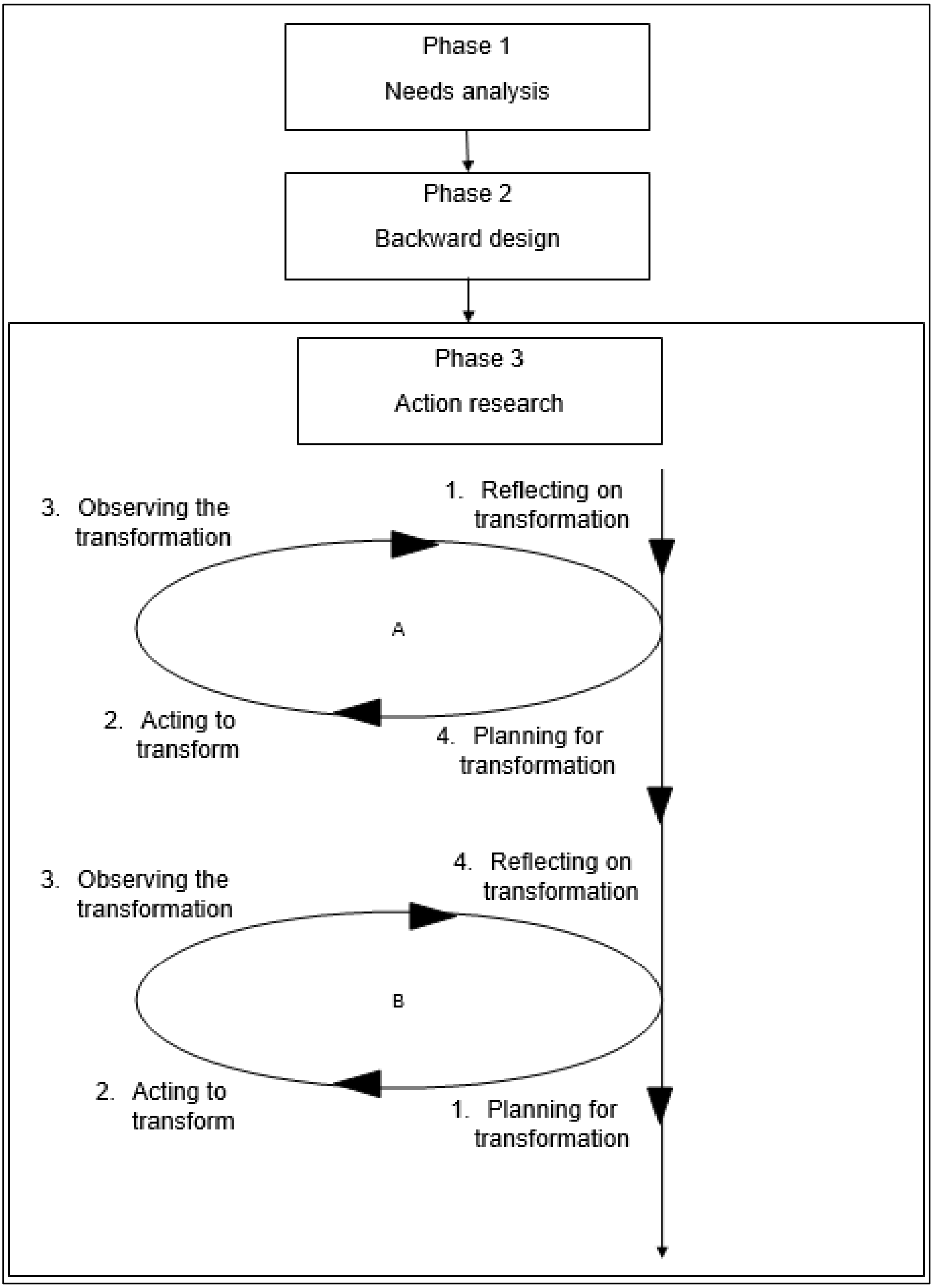
Action research is fundamentally characterised by a cyclical procedure that encompasses planning for transformation, acting to transform, observation of possible transformation, and reflection on possible transformation (Burns, 2005). This iterative nature harmoniously corresponds to the principles of Whole Brain® thinking (Herrmann Global LLC, 2022). My model, as illustrated in Figure 3, includes frequent reflections on the efficacy of strategies of facilitating learning, taking into account the varied thinking preferences of the learners. This process of reflection enables ongoing transformation, guaranteeing that the curriculum remains adaptable to the changing requirements and preferences of the fourth-Grade learners.

1.6.5 Action research-driven curriculum Development

In the representation of the model I developed, I present three phases (as illustrated in Figure 4).

Figure 4

Curriculum development plan



In my study, the first phase involves conducting a needs analysis, which is essential for curriculum design. This investigation, as described by Zohoorian (2015), includes examining the profile of learners, encompassing aspects such as their background, strengths and weaknesses, cognitive abilities, the learning environment, and the conditions under which they learn. Understanding these factors is crucial for designing a curriculum that effectively meets the needs of the learners.

In assessing learners' strengths and weaknesses, I considered various aspects related to their cognitive abilities, including problem-solving competencies, critical thinking abilities, creativity, memory retention, and information processing. To evaluate these cognitive abilities, I planned to use a combination of methods such as observation, interviews, standardised tests, and possibly cognitive tasks designed specifically for this purpose. Gathering data through these methods will provide a comprehensive understanding of learners' cognitive abilities and how these factors can influence their learning experiences and needs.

The needs analysis I conducted is based on the Kaufman Model of needs assessment. In his seminal work, Kaufman (1977) describes needs analysis as the process of determining gaps between the present and the desired outcomes and prioritising the filling of the gaps. He further explains that curriculum development should address these gaps to achieve educational change. Although the construct 'educational change' is commonly used in the literature, I refer to 'educational transformation' as I seek to transform my practice – as I consider myself a transformational practitioner. The notion of transforming practice is highlighted in the work of Du Toit (2013). The construct of transforming practice has been a key focus of educational research and theory, with scholars seeking to understand how to improve teaching and learning in diverse contexts. According to Du Toit (2013), transforming practice is essential for developing just and efficient educational systems. He describes the process of "changing the methods in which we do things, to ensure that we do things differently and better" as "transforming practice" (p. 2). To achieve this, it is necessary to question established norms and beliefs and work toward inclusive, democratic, participatory means of facilitating learning and methods of learning.

The second phase involved backward design. It relates to the competencies that learners should be able to demonstrate by the completion of the curriculum, developing accountable assessment opportunities that would confirm the learners' competencies and the learning opportunities created for learners to master these competencies.

Phase 3 refers to the actual use of action research principles. This phase also consists of different spirals consisting of different cycles. Each cycle consists of four steps, namely, planning for transformation or innovation, acting out the innovation, observation of the initiative and a reflection on the process of implementing the plan. The spiral in the middle, indicated by a thick line, represents my action research and professional development – as the researcher.

The implementation of Phase 3 took place during the offering of the programme – once a week, for three terms. The programme progressed as the curriculum development progressed in tandem. Thus, as the programme was planned step-by-step, it is implemented in the same step-by-step fashion. The A and B cycles refer to the first two action research cycles that were conducted, each of which covered one learning opportunity. The steps within the action research spirals were discussed in section 1.6.3.

This approach allows for continuous improvement and adaptation of the curriculum to meet the evolving needs of learners. Through these phases, I aim to not only develop a curriculum but also transform my practice as an educator, following the principles of inclusive, democratic, and participatory learning.

1.7 Methodological landscape

Mohajan (2018) is of the view that all research should be grounded on a plan. This includes paradigms, methodologies and designs that guide the research.

1.7.1 Research philosophy

Crossan (2003) states that a research philosophy is a set of beliefs that guide research actions. It also aids a researcher in their understanding of the nature of reality (ontology), and knowledge creation (epistemology) (Kivunja & Kuyini, 2017). Ontology and epistemology guide the researcher with data collection and data analysis during the study. My ontological and epistemological orientation is consequently briefly explained.

1.7.1.1 Ontology

Ontology refers to the study or perception of reality (Mabila et al., 2017; Sefotho, 2018). I used an interpretive ontological stance. Interpretivism refers to the belief that multiple realities exist (Maree, 2016) and knowledge is created by subjective experiences (Leavy, 2017). This stance looks at, among other aspects, the different subjective perceptions of participants by using, inter alia, observations, focus group interviews and semi-structured interviews. I aimed to investigate my teaching practice as a micro educational cosmos, forming part of the world through participants; subjective meanings and reasonings. I interviewed learners in focus groups in a semi-structured fashion to gain a deeper understanding of their insights, feelings and views about the envisaged curriculum – at a cognitive and practical level. My understanding of how knowledge is acquired has greatly influenced my worldview, especially in the context of education.

1.7.1.2 Epistemology

Epistemology refers to the social world and the knowledge that can be discovered and created from this world (Maree, 2016; McNiff, 2016). I used socio-constructivism to construct knowledge about the social world, especially the educational world in which I find myself. Constructivists state that knowledge is gained and constructed by interacting with other people (Myburgh & Tammaro, 2013). However, this is only part of the process of constructing meaning – it is also about engaging relevant literature and learning from my own practice.

1.7.1.3 Qualitative research

In essence, I made use of qualitative research. Qualitative research is concerned with data sets that make use of text and descriptions, not numerical values (Leedy & Ormrod, 2015; Maree, 2016; Neuman, 2014). Qualitative research aims to understand situations in their natural environment (Leedy et al., 2019) and focuses on understanding experiences from the perspective of the individuals experiencing them (Rudestam & Newton, 2015).

Qualitative research exhibits a strong association with socio-constructivism owing to their shared philosophical foundations, which prioritise the subjective aspect of reality, the significance of context, and the role of human interpretation in comprehending social phenomena (Creswell, 2014).

In summary, qualitative research, and socio-constructivism exhibit strong compatibility with the use of action research in the creation of a curriculum development framework tailored to primary school coding and robotics. These philosophical perspectives prioritise the comprehension of individual viewpoints, the consideration of social circumstances, and the encouragement of active involvement, all of which are crucial for the development of a curriculum that is both meaningful and effective.

1.7.2 Research strategy

I used action research as a research design. This was complemented by auto-ethnography.

The utilisation of Whole Brain® thinking as the innovation and professional development strategy was implemented during Phase 3 of the curriculum development process. The action research process was subject to constant monitoring during its separate cycles.

1.7.2.1 Action research design

The proposed innovation and professional development strategy was used in Phase 3 of the curriculum development process. It was continuously monitored during the respective cycles of the action research process.

1.7.2.2 Auto-ethnography

Ethnography refers to studying a group of people with the same beliefs, values and practices (Christensen et al., 2015; Leedy et al., 2019). It also refers to studying participants in their natural environment (Schensul et al., 2013). Christensen et al. (2015) assert that one of the most important aspects of ethnographic research is the researcher acting as participant observer. Christensen et al. (2015) explain that participant observation refers to the researcher being an active participant in the research. As my study deals a lot with self-study, I refined the ethnography as auto-ethnography (Du Toit, 2017). Here the focus is on the self – one person looking into what she is doing. With writing an autobiography of self by the self, auto-ethnography is a scholarly account of one's professional conduct by the self.

As alluded to above I worked towards developing this curriculum. Therefore, I took on the role of a participant observer, which means that I was both a part of the group being studied (comprising the learners and myself) and present during the learning experiences.

1.7.3 Data collection

Data collection occurred throughout the action research cycles.

1.7.3.1 Observations

Observations require fieldwork where the researcher investigates the context and situation (Creswell & Poth, 2019; Kawulich, 2012; Leedy & Ormrod, 2015). According to Kawulich (2012) observations are used to record data that cannot be gathered through interviews. I used classroom and learner observations to gather data not gathered through the interviews. I used pre-designed observation sheets to guide my observations during each learning opportunity and to ensure that I focus on data that would most likely contribute to the scholarly quality of my study. The pre-designed observation sheets focused on learner engagement, classroom collaboration and communication, problem-solving, technical competencies, critical thinking, creativity and innovation, time management, questions and challenges, and safety protocols. This enabled me to take notes and write down my thoughts under specified headings.

1.7.3.2 Herrmann Brain Dominance Instrument (HBDI®)

I used the Herrmann Brain Dominance Instrument (HBDI®) (Herrmann, 1995) to identify my thinking preferences. This supported my suggestion of using the model of Whole Brain® thinking as the principal learning theory. The HBDI® generates both qualitative and quantitative data (Bunderson, 1995; De Boer et al., 2013; De Boer et al., 2015). The brain profiling that was done is reported by means of a visual representation and a short narrative – qualitative in nature. In addition, based on the 120 items questionnaire, sets of quantitative data were generated. It comes in the form of numbers tabled per the different sections of the instrument. Data generated by the HBDI® was used as baseline data – a point of departure for the research I conducted and the learning opportunities I designed.

1.7.3.3 Photo voicing and photo evidence

As early as 1997, Wang and Burris established that photo voice is a data collection tool that provides a practical way to illustrate the lived experiences of research participants. Creswell and Creswell (2018) explain that photo voice serves as a visual representation of the individual's experiential "voice". I took pictures of participants' work, such as learners' robots, programming code and worksheets, during the cycle. These photos reflect the lived experiences of the learners.

1.7.3.4 Text analysis

Text analysis, as explained by Du Toit (2012), refers to the study of material, such as lesson plans, worksheets, etcetera, to gain insight from text created as part of the learning process or as educational material complementing the facilitation of learning. In the context of integrating coding and robotics into the curriculum, text analysis can involve examining students' written reflections, analysing educational texts related to coding and robotics, or studying instructional materials to enhance teaching strategies. This method can provide valuable insights into the effectiveness of the curriculum and the impact of coding and robotics on student learning outcomes. I analysed texts such as scripts used to document completed assessments, plans for learning opportunities and reflections to identify any themes that emerge from the text.

1.7.3.5 Semi-structured interviews

Semi-structured interviews refer to interviews where a researcher follow a list of predetermined questions, followed up with questions to clarify a person's reasoning (Leedy et al., 2019). The researcher asks follow up questions to prompt the participant to provide additional information (Christensen et al., 2015). I conducted semi-structured interviews with learners after receiving their consent and the assent of the parents. I then explained the purpose of the focus group, and set ground rules for respectful and constructive conversation. Learners took part in focus group interviews. They were divided into groups of four ensuring a mix of skill levels and background knowledge within the groups. Thereafter, I followed the interview guide, asked questions and encouraged participants to share their thoughts and lived experiences. I actively listened to the participants, and probed for more information when necessary. I ensured that all participants had an opportunity to contribute. The interview questions for the learners were derived from the Action Research Curriculum Development model.

1.7.3.6 Field notes

Field notes are the action of taking notes of data as it takes place (Kawulich, 2012; Leedy et al., 2019). I used field notes to gather data that cannot be gathered by listening to the voice recording of the semi-structured interviews. I took general notes such as the lived experiences of learners and the educator as the classes progressed, the chronological progress of the actual learning opportunities, the distinct thinking preferences involved during facilitating and assessing learning, as determined in the planning of the learning opportunities. After taking field notes, I wrote a reflection on my experience of each opportunity.

1.7.3.7 Journaling and reflection

A journal provides a data set of the researcher’s thoughts and reflections on the learning opportunities (Hayman et al., 2012) prior to, during and after the learning opportunities (Schön, 1991). I kept a journal of each class. Before a learning opportunity, I used a journal to set my goals, review previous knowledge, and anticipated challenges. During a learning opportunity, I used a journal to record key points, note questions, or challenges, and note successes. After a learning opportunity, I used a journal to summarise the learning opportunity, evaluate the learning opportunity, and plan for improvement. This journal noted all data that cannot be gathered from the interviews.

1.8 Execution of data analysis plan

Data analysis took place during the fourth step of the action research cycles. During this step I used the Creswell data analysis steps to analyse the data received during the text analysis, semi-structured interviews, observations, field notes, and journaling. Creswell and Poth (2019) suggested the following steps:

i. Organising the data and breaking large sections into smaller units. I organised the data according to my research questions.

ii. Obtaining an overview of the data. Here I read through the data to ensure that I understand all aspects of the data.

iii. Developing categories and finding patterns or themes in the data. I used Atlas.ti 23 to assist here. Atlas.ti 23 is a software program that helps with data analysis in research (ATLAS.ti 23, 2017). I made use of open coding and axial coding to code the interview transcripts, field notes from observations, photos, and my journal entries. Open coding entails reading of text such as transcribed interviews, observation notes and field notes to get an overview of emerging themes in the data and then dividing the data into these themes (Creswell & Poth, 2019; Leedy et al., 2019). Axial coding involves connecting and aligning the themes identified while doing open coding (Creswell & Poth, 2019; Leedy et al., 2019).

iv. Synthesis of data. Here, I synthesised data into one coherent document and presented it in my research findings.

1.9 Conclusion

This action research (AR) study aimed to develop a Grade 4 coding and robotics curriculum for an independent South African primary school. This curriculum development study used an action research trajectory to monitor the development process and the backward design model to create an authentic competency-based curriculum. This curriculum allowed learners to develop their problem-solving, critical thinking, collaboration, and creativity competencies by building a LEGO® Minecraft EV3 robot and coding the robot to perform basic tasks such as basic movement, having lights, and basic graphics. This curriculum will be tested in action research cycles, where a previous cycle informed the next cycle. I also used pre and post interviews with learners and the educator to determine a new action plan for the next cycle. This study aligns with the interpretive philosophy and socio-constructivist paradigm, which states that there exist multiple accounts of the truth and that knowledge is gained through social interaction. The data collection methods included semi-structured interviews, field notes, and observations. The data analysis method consists of the Data Analysis Spiral developed by Creswell (2014). This study could benefit the learners and other schools planning to implement coding and robotics as a subject.

2. CHAPTER 2: READING SCHOLARS OF NOTE USING DIFFERENT FRAMES OF MIND

2.1 Introduction

"The purpose of literature is to turn blood into ink." T.S. Eliot (1933)

This quote by Eliot written in 1933 perfectly captures the essence of literature and its power to transform personal lived experiences into works of art that can be shared with the world. Literature has the ability to evoke emotions, inspire thoughts and spark academic discourse. A literature review is a systematic examination of existing research and published works on a specific topic (Christensen et al., 2015; Maree, 2020). It provides an overview of the current state of knowledge and identifies gaps in the existing research that needs to be addressed (Christensen et al., 2015). The purpose of a literature review is to gain a comprehensive understanding of a topic, identify patterns and themes in the existing research, and inform future research directions (Leedy et al., 2019; Maree, 2020). This literature review aims to delve into the existing body of research on coding and robotics in the classroom.

However, what is absent in most scholarly work, is the reference to the fact that two bodies of scholarship are to be engaged. Firstly, what is common in most literature is the focus on the body of knowledge pertaining to a field of specialisation. I would refer to a scholarship of a discipline. Secondly, the missing link is the contribution to the scholarship of research methodology. My reading of scholars of note includes consulting literature on curriculum and related theories; and literature on scholarship of action research.

It should be noted that a literature review, as it is commonly referred to, does not span one single chapter – usually Chapter 2. Literature is referred to throughout my study. It is from this literature that I derived constructs to work with and that offered me the basis for constructing new meaning. It, therefore, makes sense to note that the construct frame spans all the chapters. This idea of a literature review as being more than reporting what one has consulted in a single chapter is promoted by Booth et al. (2016).

A literature review entails a critical and systematic examination of existing research, scholarly publications, books, and other pertinent sources pertaining to a specific subject matter, research inquiry, or field of study (Christensen et al., 2015; Leedy et al., 2019; Maree, 2020). These researchers claim that it has a number of uses, such as identifying knowledge gaps, assessing prior research, establishing a theoretical framework, and guiding future studies.

In this section, I firstly present an overview of the available literature. The relevant critical bodies of knowledge include (i) industrial revolutions as frame of mind, (ii) the perceived impact of the 4IR on education, (iii) 21st century competencies, (iv) assessment for and of learning, (v) coding and robotics (vi) curriculum development (vii) needs analysis for the implementation of a Whole Brain® coding and robotics curriculum (viii) educator professional development and (ix) Whole Brain® thinking.

Secondly, I present a construct frame for constructing a relevant curriculum. Given the inherent characteristics of this research, a construct frame was designed and employed during the development of an action research-driven Whole Brain® coding and robotics curriculum. It is worth noting that this curriculum has the potential for future expansion and enhancement. As a result, the construct frame is visually presented and subsequently discussed in a concise manner.

This literature review not only paves the way for my research but also underscores the dynamic nature of knowledge creation and its application in the field of education. Therefore, the next section of my study delved deeper into the construct of frames of mind, further enriching my understanding of this crucial aspect.

2.2 Frames of mind

2.2.1 Industrial revolutions

To understand the innovations in the world of technology in general, but the world of education specifically, it is essential to give new meaning to the four industrial revolutions that occurred and to discuss them briefly. According to Daemmrich (2017), an industrial revolution refers to technological advances that continuously transform traditional ways of doing things. Kayembe and Nel (2019) explain that an industrial revolution refers to a significant technological "development, change or transformation" that influences society, placing emphasis on human involvement (p. 80). In my view, an industrial revolution refers to technological advancement with a profound impact on society. Ultimately, the industrial revolution was a significant turning point in the history of mankind, ushering in a modern society marked by technological advancement, and urbanisation.

There have been three industrial revolutions throughout history, and according to Daemmrich (2017), the fourth industrial revolution has already started. The following are only a few of the sectors that are impacted: construction (Cook, 2021), higher education (Kayembe & Nel, 2019; Penprase, 2018), biology and engineering (Membrillo-Hernández et al., 2020), and mining (Harmse et al., 2022).

The first industrial revolution occurred from about the 1700s to the 1800s (Oke & Fernandes, 2020). During this time, the railroads were constructed, and the steam engine was invented, dramatically increasing production and stock exchange (Kayembe & Nel, 2019; Oke & Fernandes, 2020; Schwab, 2017). In his seminal work Berlanstein (1992) describes this industrial revolution as transitioning from hand production to machine production and in my view, to a Whole Brain® frame of mind seeing that production still requires human input in the production process and acquisition of products.

The second industrial revolution started around the late 19th century and ended in the early 20th century (Kayembe & Nel, 2019). This industrial revolution is known as the "Technological Revolution" (Mokyr & Strotz, 1998). According to Schwab (2017) and Daemmrich (2017), the advent of the industrial revolution marked the commencement of mass production, which was facilitated by the introduction of the moving production line and the discovery of electricity. Daemmrich (2017) points out that this led to a further increase in production, and in turn, having an impact on society.

The third industrial revolution, also called the digital revolution, began in the 1960s and ended in the 1990s (Kayembe & Nel, 2019; Schwab, 2017). This industrial revolution was marked by the rapid development of information technology (Didier, 2024; Greenwood, 1997). Kayembe and Nel (2019) pointed out that during this revolution, semiconductors, computing, personal computers, and the internet developed. Greenwood (1997) asserts that this revolution has had a major effect on the global economy and society as a whole, bringing about enormous changes in the manner that goods were created, disseminated, and consumed. Schwab (2017) and Troxler (2013) are of the view that the use of big data analytics to improve manufacturing processes is one of the main characteristics of the third industrial revolution. According to Schwab (2017), businesses can utilise extensive data sets to analyse patterns and trends, which can subsequently be employed to optimise operations, reduce inefficiencies, and enhance overall quality.

As a result, production and efficiency have significantly improved, which has reduced the cost of goods and raised competition. According to Troxler (2013) the third industrial revolution also saw the rise of additive manufacturing, or 3D printing, as a key change. Layer by layer construction of complicated structures is now possible thanks to technology, which is considerably more adaptable and effective than conventional manufacturing processes (Troxler, 2013). Schwab (2017) and Troxler (2013) describe how this has led to a decline in the requirement for massive factories while simultaneously allowing for increased product customisation and individualisation. These authors also explain that the labour market has been significantly impacted by the 3IR. Many conventional manufacturing occupations are being displaced by machines as automation and robots grow increasingly common (Azmi et al., 2018; Schwab, 2017). Yet, it has also led to new employment prospects in industries like robotics engineering, software development, and data analytics (Troxler, 2013). Kayembe and Nel (2019) report that due to the change in industries, workers now need to acquire new competencies and learn how to use new technology, which necessitated a substantial investment in education and training programmes.

According to Didier (2024), Moll (2023), Daemmrich (2017) and Schwab (2017), the fourth industrial revolution (4IR), sometimes known as Industry 4.0, is only getting started. It advances the three previous industrial revolutions – mechanisation, electrification, and computerisation – and is characterised by a convergence of technologies that is blurring the distinctions between the physical, digital, and biological domains (Kayembe & Nel, 2019; Schwab, 2017). One of the key technologies driving this convergence is artificial intelligence (AI), which enables machines to learn, reason, and interact with humans and other systems (Endeley & Zama, 2021; Oke & Fernandes, 2020). According to Schwab (2017) and Oke and Fernandes (2020), the results of this industrial revolution are still unknown. Still, Schwab (2017) states that although technologies cannot replace humans, technologies can be more efficient than humans in performing tasks, referring to the shift towards a Whole Brain® frame of mind. Endeley and Zama (2021) added that the 4IR is the ongoing automation of traditional industries by using modern smart technology, which will also have an impact on educational practices. New and inventive goods, services, and business models that are altering how we work and live are also being developed as a result of the 4IR. To fully explore the potential benefits of the Fourth Industrial Revolution, governments, corporations, and individuals must be aware of these advances and adapt to the new reality.

2.2.1.1 Perceived impact of the 4IR on education

Implied in the word 'education' are all levels of education: preschool, primary school, high school, universities, TVET colleges (colleges for vocational education and training), informal post school education, etcetera. Although the implications of the 4IR are still unknown and primitive due to the 4IR being in the early stages of development, according to Butler-Adam (2018), Reaves (2019), Kayembe and Nel (2019) and Carrim (2022), the perceived implications on education so far are extensive, whether positive or negative. As such, Kayembe and Nel (2019) points out that the 4IR holds both challenges and opportunities for education.

While the 4IR has brought forth many technical breakthroughs that have made education more convenient and accessible for some learners (Sinha et al., 2023) it has not necessarily done so for everyone (Lembani et al., 2020). The digital divide remains a significant barrier to acquiring an education, as it creates disparities between individuals who possess technological access and those who do not (Lembani et al., 2020).

Another concern, although not acknowledged by many authors, is that 4IR may widen the existing gap between those who have access to technology and those who do not (Carrim, 2022; Kayembe & Nel, 2019; Serrano-Ausejo & Mårell-Olsson, 2024; Sinha et al., 2023). Sinha et al. (2023) argue that not only access to technology influences this gap, but also data and internet access. Oke and Fernandes (2020) highlight that this disparity can limit the opportunities for those who do not have access to technology, putting them at a disadvantage in the job market. Moreover, it can also perpetuate existing inequalities, as learners from low income families may not have access to the same resources as their wealthier peers (Kayembe & Nel, 2019). While digital tools and online learning platforms have given some learners more flexibility and convenience in their education (Sinha et al., 2023), not everyone has access to the computers and high speed internet these resources require (Oyedemi & Mogano, 2017). This is especially true in underdeveloped nations and low income areas where access to technology is constrained (Azubuike et al., 2021).

Additionally, the 4IR has improved the adaptability of education for some learners and educators (Sinha et al., 2023) but one of the main obstacles to using technology to improve the adaptability of education is that it necessitates a certain level of digital literacy and access to technology (Azubuike et al., 2021; Cetindamar Kozanoglu & Abedin, 2021), which may not be available to all learners and educators, especially those from disadvantaged backgrounds. In addition, while online learning platforms and digital resources have the potential to make education more flexible and adaptable, they also require a high level of self-discipline and motivation on the part of learners, which according to Esra and Sevilen (2021) not all learners possess.

Another concern is that the increasing use of technology may lead to a decrease in critical thinking and problem-solving competencies (Oke & Fernandes, 2020; Van Laar et al., 2020). According to Carrim (2022) and Van Laar et al. (2020) critical thinking is the process of systematically and logically examining information or arguments to make informed decisions and conclusions. According to Oke and Fernandes (2020), critical thinking encompasses the examination of assumptions, biases, strengths, and weaknesses within an argument or construct, with the purpose of identifying these components and subsequently drawing conclusions based on the analysis. According to Carrim (2022) problem-solving is the process of finding answers to intricate or challenging difficulties or challenges. According to Van Laar et al. (2020), problem-solving competencies encompass the process of identifying the problem, evaluating the situation, and devising and implementing a strategy or plan to address it. Carrim (2022) and Oke and Fernandes (2020) delineate that as learners become more reliant on technology to provide answers, they may not develop the competencies they need to think critically and solve complex problems independently. Some of the key competencies that will be necessary for learners in a technology driven world are discussed in section 2.2.2.2. Additionally, Oke and Fernandes (2020) and Van Laar et al. (2020) emphasise that there is also a concern that the use of technology may lead to a lack of interpersonal competencies and emotional intelligence, as learners become less likely to interact with their peers and educators in person.

Moreover, the rapid rate of technological advancements necessitates a continuous adaptation of the education system in order to remain current. According to the studies conducted by Kayembe and Nel (2019) as well as Oke and Fernandes (2020), the integration of new technologies and infrastructure poses a considerable challenge for educational institutions such as schools and universities. Sinha et al. (2023) add that this can be costly, and schools may struggle to keep up with the changes, especially if they do not have adequate funding. According to Spaull (2019) there is a significant disparity in the infrastructure available in public versus private schools in South Africa. While private schools frequently have access to better facilities and resources, such as modern classrooms, well stocked laboratories, and cutting edge technology (Spaull, 2019), many public schools in South Africa struggle to provide even the most basic amenities (Du Plessis & Mestry, 2019; Equal Education, 2016; Sutherland, 2020). The South African Human Rights Commission (2019) found that many public schools in the nation lack the most basic amenities, including effective sanitisation systems, clean drinking water, and secure classrooms. Additionally, a lot of rural schools have trouble getting electricity and internet access, which might hinder their capacity to deliver high quality education (Anon., 2020; Dube, 2020; Landa et al., 2021). Private schools in South Africa, in contrast, frequently have access to more resources, which enables them to offer a wider choice of educational options to their learners (Liebenberg, 2022; Tadesse & Muluye, 2020). Private schools often have smaller class sizes, which can lead to a more personalised approach to education, as well as access to modern facilities and resources (Liebenberg, 2022; Tadesse & Muluye, 2020).

The impact of 4IR on education is complex and multifaceted. On the one hand, technology has made education more accessible for some learners, providing learners with a more engaging and interactive learning experience. On the other hand, there are also concerns about the potential negative impacts of technology on critical thinking, and interpersonal competencies. As technology continues to evolve, it is important for schools and universities to find ways to balance the benefits and drawbacks of the 4IR in education. This may involve investing in technology that supports personalised learning, while also promoting the 21st century competencies (discussed in section 2.2.2.2). Ultimately, the impact of the 4IR on education will depend on how we choose to use relevant technology.

2.2.1.2 Perceived changes needed in education to adapt to the 4IR

As stated above the 4IR is rapidly transforming the world, bringing with it new technologies, innovative processes, novel ways of thinking (Brown-Martin, 2017; Oke & Fernandes, 2020) such as Whole Brain® thinking. In order to adequately equip the upcoming generation for achievement in the dynamic technological environment, it is imperative that the education system undergo a transformation to align with the requirements of the 4IR. This section outlines some of the perceived changes needed in education to ensure that learners are equipped with the competencies and insight necessary to thrive in the 4IR. The 4IR influences policies, curricula, teaching and learning, and new competencies needed to be relevant in the workplace (Butler-Adam, 2018; Daemmrich, 2017; Schwab, 2017).

Firstly, policies and curricula must be adapted to include competencies perceived to be needed to function in the 4IR (Magagula & Awodiji, 2024). With new technologies emerging all the time, it is essential that educators create opportunities for learners to develop the competencies to use these technologies effectively and to understand and navigate this rapidly changing technological landscape. According to Kayembe and Nel (2019) and Butler-Adam (2018), the education system should be reinvented to improve learners' creative and innovative thinking and prioritise the development of technical competencies such as coding and data analysis.

Secondly, another important change needed in education is the development of interdisciplinary, transdisciplinary and multidisciplinary thinking competencies (Repko & Szostak, 2020). Interdisciplinary, transdisciplinary, and multidisciplinary thinking competencies encompass distinct approaches to problem-solving and knowledge integration, which entail the utilisation of diverse methods that cross conventional disciplinary boundaries (Uwizeyimana & Basheka, 2017). The construct of multidisciplinary thinking entails the utilisation of various disciplines in parallel, without a comprehensive integration of their respective approaches (Laurel, 2018). Interdisciplinary thinking refers to the process of establishing connections between various academic disciplines and constructing a shared constructual framework (Laurel, 2018; Smothers, 2020). Transdisciplinary thinking refers to the inclusion of various disciplines as well as diverse stakeholders, including citizens, policymakers, and professionals, in the research process (Daneshpour & Kwegyir-Afful, 2022; Uwizeyimana & Basheka, 2017). According to Kayembe and Nel (2019), in the context of the 4IR, possessing expertise in a single subject area (as stated in the CAPS document) is no longer deemed satisfactory. Instead, learners must be able to work across multiple disciplines, integrate information from a variety of sources, and collaborate effectively with others from fields of specialisation other than one's own, so-called multidisciplinary teams. Education must reflect this by emphasising interdisciplinary learning and project-based approaches that help learners develop these valuable competencies. Butler-Adam (2018) and Kayembe and Nel (2019) clarify that cross-sector or interdisciplinary teaching and learning refers to a teaching approach in which educators from different sectors, such as industry and academia, collaborate to provide well-rounded education. When two or more academic fields work together to achieve a common goal, such as when computer scientists, psychologists, and sociologists work together to create human/computer interfaces, this is referred to as multidisciplinary (Weller & Appleby, 2021). Holley (2009) connects the notions of cooperative learning between scholars and practitioners to the idea of transdisciplinary.

Thirdly, in addition to interdisciplinary competencies, it is also important that education prioritises the development of critical thinking and problem-solving competencies. Magagula and Awodiji (2024) and Lathifah et al. (2019) point out that education is expected to provide learners with the opportunity to be directly involved in learning experiences to build critical thinking, problem-solving and social competencies. According to Kayembe and Nel (2019), learners must be able to analyse complex problems and come up with innovative solutions. Education must reflect this by providing learners with opportunities to engage in hands-on, experiential learning and to work on real world projects that challenge them to think creatively (Butler-Adam, 2018; Kayembe & Nel, 2019; Lathifah et al., 2019).

Finally, the education system must also adapt to the changing nature of work in the 4IR. Kayembe and Nel (2019) assert that with increasing automation and the rise of short term, project-based work, it is important that learners are prepared for a highly flexible and rapidly changing job market. According to Stanford (2017), short term, project-based work is defined as tasks completed by independent contractors or business owners who often use websites or mobile apps. Stanford (2017) points out that it usually entails working on a task or project by task basis as opposed to being employed by a single organisation. This is a result of the automation of processes and production. Consequently, many jobs that require manual and physical competencies will decline (Oke & Fernandes, 2020). Learners must develop a new set of competencies that are in line with the changing demands of the workforce if they want to succeed in the 4IR labour market. The ability to manage, implement, and work effectively with new technologies is becoming a growing necessity (Butler-Adam, 2018; Gibbs, 2022; Strack et al., 2021). In order to continually upskill and reskill to remain employable, learners must be equipped with the capacity to learn and relearn throughout their lives (Butler-Adam, 2018). Additionally, learners will be able to create their own chances in the economy where self-employment and freelancing are becoming more common by developing entrepreneurial competencies and an innovative attitude (Butler-Adam, 2018; Strack et al., 2021).

In my view, the United Nations' sustainability goals may also be included in the perceived changes in education. The sustainability goals place emphasis on quality education. To ensure quality education, educational systems must engage with and react to shifting labour markets and technology advancements as outlined in the global sustainability agenda for education 2030, goal 4 (Agbedahin, 2019). One of the main outcomes of this goal is to ensure that all youth and adults have the necessary abilities for employment, respectable jobs, and entrepreneurship, including technical and vocational competencies (United Nations, 2022). As reported by PricewaterhouseCoopers (PWC) (2020), there is considerable variation in the level of technological advancement observed across different global goals, nations, and even within national boundaries. Implementing new technology solutions may be far more difficult in locations with weak or non-existent infrastructure to support digital and other 4IR technologies creating a challenge for technology implementation (PricewaterhouseCoopers, 2020; Sutherland, 2020), as discussed in section 2.2.1.1. According to PWC (2020) the 4IR in line with these goals may lead to many different types of opportunity for education. These opportunities include augmented reality, artificial intelligence (AI) and virtual reality (VR) experiences for remote learning, automating and accelerating the work of educators, online open courses and 4IR enabled personalised and adaptive learning, and technology-based assessments to make it easier to provide ongoing feedback, digital curricula, learning opportunity plans, and competencies across devices, tools for managing educators and school resources, etcetera.

2.2.2 Twenty first century competencies

The 21st century has brought about many changes in the way we live and work, and as a result, new competencies are required to thrive in this rapidly changing world. The so-called 21st century competencies are a combination of traditional competencies, such as critical thinking, problem-solving and communication, and technological competencies (Amri et al., 2019; Reaves, 2019; Voogt & Roblin, 2012). These competencies are not only important for success in the workforce but also for success in life in general. In the subsequent analysis, I highlighted five 21st century competencies, namely critical thinking, problem-solving, effective communication, collaboration and teamwork, and flexibility and adaptability along with a discussion on their significance.

The first 21st century skill of importance is technological competencies. Chen et al. (2018) is of the view that with the rapid advancement of technology, it is essential for learners to be able to use and understand a variety of digital tools and platforms. Cetindamar Kozanoglu and Abedin (2021) and Herold (2018) point out that in the workforce, technological competencies are increasingly important as many jobs now require the use of digital tools and platforms, and employees must be able to effectively use them to complete tasks and communicate with others.

Two other 21st century competencies I would like to highlight are critical thinking and problem-solving. According to Stauffer (2022), Van Laar et al. (2020), Van Laar et al. (2017) in a world filled with complex challenges and problems, individuals must be able to analyse information, evaluate options, and make decisions in a timely manner. Scholars such as Khoiri et al. (2021) and Lathifah et al. (2019) explain that critical thinking and problem-solving competencies are essential for success in both personal and professional life, as individuals must be able to evaluate situations, identify potential solutions, and make decisions that will lead to the best outcome.

In addition to critical thinking and problem-solving, effective communication is another important 21st century skill. In a world that is increasingly connected, it is essential for individuals to be able to communicate effectively with others, both in person and online (Kivunja, 2015; Stauffer, 2019). These scholars discuss that this includes being able to express oneself clearly, listen actively, and understand the perspectives of others. Hobbs and Frost (2003) further explain that effective communication is essential for success in the workforce, as employees must be able to work effectively with others, communicate ideas and solutions, and build strong working relationships.

Collaboration and teamwork are also important 21st century competencies. Researchers such as Stauffer (2019) and Kift et al. (2010) explain that in a rapidly changing and complex world, individuals must be able to work effectively with others to achieve common goals. Alber (2012) and Killen (2013) say that this requires the ability to collaborate, negotiate, and resolve conflicts, as well as the ability to contribute one's own ideas and perspectives to a group effort. In the workplace, employees must be able to work effectively with others to complete projects and achieve organisational goals.

Flexibility and adaptability are important 21st century competencies. In a world that is constantly changing, individuals must be able to adjust to new circumstances and be open to new ideas and approaches (Khoiri et al., 2021). Dishon and Gilead (2021) detail that this requires a willingness to learn and an ability to adapt to new situations and challenges, as well as an openness to change and a willingness to embrace new perspectives. Khoiri et al. (2021) and Lathifah et al. (2019), delineate that in order to remain competitive and relevant in a workplace that is always changing, individuals must be able to adapt to new situations and be receptive to new ideas.

2.2.2.1 Additional competencies

Reaves (2019) states that technological literacy, critical thinking and problem-solving, effective communication, collaboration and teamwork and flexibility and adaptability are constantly altering to fit with the extreme developments of the 4IR. Additionally, Ramey (2016) emphasises that it is about ways of thinking and behaviours that support success in a time of fast evolving and expanding technology. Preferred ways of thinking are encapsulated in the theory on Whole Brain® thinking. Since Whole Brain® thinking is needed to maximise one's potential, it would be contemporary thinking to include it in the list of 21st century competencies along with technological literacy, critical thinking and problem-solving, effective communication, collaboration and teamwork and flexibility and adaptability. The Whole Brain® thinking model presents the various thinking preferences that people exhibit. The well-known left brain right brain research into brain specialisation (Herrmann-Nehdi, 2010) served as the inspiration for the construct of a "whole brain" at first. It has now developed into a helpful but frequently ill-defined framework for learning and performance (Herrmann-Nehdi, 2010). Herrmann-Nehdi (2010) and De Boer et al. (2001) state that, different regions of the brain work in tandem, forming intricate neural networks that facilitate various cognitive processes. Herrmann-Nehdi (2010) and De Boer et al. (2001) suggest that the brain exhibits certain preferences when it comes to modes of thinking. While individuals may differ in their thinking preferences, some general patterns have been identified, namely analytical thinking, sequential thinking, interpersonal thinking and imaginative thinking (Herrmann, 1999). Just as the brain has preferred modes of thinking, it also exhibits preferences in how it processes and assimilates new information (Palasigue, 2009). These preferences can influence an individual's learning preferences and the effectiveness of learning experiences (Deshpande, 2010). These modes of learning include visual learning, auditory learning and kinaesthetic learning (Herrmann-Nehdi, 2010).

2.2.2.2 Relevance of this study for 21st century competencies

The study of 21st century competencies is necessary for robotics and coding. What is learned may contribute to helping learners master and develop competencies they will need in a constantly changing world. My focus is on how to facilitate the development of the 21st century competencies discussed in section 2.2.2. Having a thorough understanding of these competencies, where they may fit into different educational contexts, would help me to gain insight into different ways to effectively plan and construct learning opportunities that will offer Grade 4 learners the opportunity to master and develop these competencies.

2.2.3 Coding and robotics

As technology flows into our surroundings more and more, the construct of technology in education is becoming increasingly apparent thanks to the spread of coding and robotics throughout the educational system. It also has an impact on critical cross field outcomes and omnipresent competencies (LEGO® Education, 2022). According to Chu and Chen (2021) and Jordaan (2019), critical cross field outcomes are essential learning outcomes that cut across a variety of academic courses, disciplines and educational settings. These outcomes highlight the competencies deemed necessary for success in the fast evolving world of today (Ntshoe & Malebo, 2021). According to Shubina and Kulakli (2019) pervasive competencies, also known as soft competencies, are a collection of competencies that are helpful and transferable across a variety of various settings, including jobs, sectors and workplaces.

2.2.3.1 Robots

Educational robots, also known as programmable toys, are designed to assist learners in creating new insight by providing a hands-on approach to learning (Anwar et al., 2019; Gunes & Kucuk, 2022; Jung & Won, 2018; Misirli & Komis, 2014). Hirst et al. (2003) describe programmable toys as pre-assembled robotic toys that encourage learners to write and execute programs to solve preset problems or achieve specific goals. Menekse et al. (2017) explain that for them robotics are educational tools that actively include learners in critical thinking and cooperative problem-solving. There are numerous robots on the market, including the LEGO® kits (Mindstorm™, Spike Essential™ and Spike Prime™), Bee Bot, Arduino and other series. In my teaching practice I use the LEGO® Spike Prime™ kit.

Beginning with the Mindstorm™ series, LEGO® quickly progressed to the more contemporary Spike™ Essential (Grades 1-5) and Prime (Grades 6-8) kits. As seen in Image 2, the Spike™ kits include an extensive primary classroom brick set with an intelligent hub, several sensors that can detect and respond to the environment, such as a colour sensor, distance sensor and pressure sensor, two small and one big motor, various connectors and cables to connect sensors, motors and other components to the hub, and a range of LEGO® accessories and blocks (LEGO® Education, 2022). The intelligent hub in the Essential kit is smaller than in the Prime kit, which is the only distinction between the two kits.

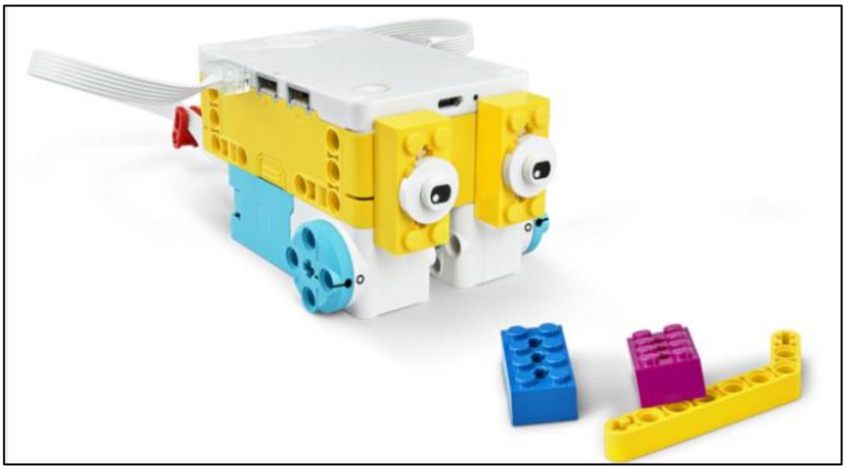
Image 2

LEGO® SPIKE Prime™ robotic set (LEGO® Education, 2022)

With these kits learners can build a variety of robots, such as the Hopper race robot illustrated in Image 3.

Image 3

Built Hopper race robot (LEGO® Education, 2022)



2.2.3.2 Coding

Coding has become a fundamental technological and cognitive skill in the digital age, allowing individuals to create their own applications, websites and software programs. To facilitate the learning process for beginners, block-based coding (as illustrated in Image 4) has gained popularity as an accessible approach to understanding the fundamentals of coding (FunTechBlog, 2022b; Sun et al., 2024). The construct 'block-based coding' refers to a visually intuitive yet conventionally structured form of coding (Codejig, 2022). Block-based coding provides a visual and intuitive approach to coding, allowing learners to grasp programming constructs without the need for writing complex lines of programming code (Codejig, 2022; Sun et al., 2024). Instead, users utilise visual building blocks to create algorithms and programming code, manipulating blocks in a drag and drop interface. This approach eliminates syntax errors and enables learners to focus on logical thinking and problem-solving (FunTechBlog, 2022a). Block-based coding programs are used to create algorithms and programming code, as illustrated in Image 24. I reported on my experimenting with the use of the LEGO® Education SPIKE™ application for coding in my teaching practice, as monitored by using the principles of action research.

Image 4

Block coding on LEGO® Education SPIKE™ application (LEGO® Education, 2023)

The programming code in Image 4 is part of the '*Help!*' learning opportunity found on the LEGO® Spike Prime™ application (LEGO® Education, 2023). The model uses a colour sensor to detect and respond to the colour tones of various objects. In the programming code depicted in Image 4, the user will initiate the program by activating the left button. The program will commence execution upon initiation. When the colour sensor detects the presence of blue, yellow or green, the tablet will emit a distinct sound corresponding to each respective colour. These sounds can be changed by the user when writing the programming code.

2.2.3.3 Opportunities that coding and robotics have for education

Coding and robotics have been developing at an exponential rate, and they have the potential to greatly impact education (Barker, 2012). The use of these technologies in the classroom can give learners a creative and engaging learning environment that most probably improves their comprehension of complex constructs (Afonso et al., 2021). Learning about coding and robotics provides learners with a variety of opportunities to hone competencies like cooperation, critical thinking and problem-solving (Palaiologou, 2020).

One of the key benefits of coding and robotics in education is that they can improve Science, Technology, Engineering and Mathematics (STEM) education. By providing learners with opportunities to develop and apply their competencies in STEM, coding and robotics can help build a strong foundation for future success in the science, technology, engineering and mathematics fields (Chu & Chen, 2021; LEGO® Education, 2022; Martín-Páez et al., 2019). Furthermore, working with coding and robotics can help learners develop a deeper understanding of how technology works and how it can be used to solve real world problems (Rifandi & Rahmi, 2019).

Pollarolo, et al. (2024), Eguchi (2014) and Lathifah et al. (2019) state that coding and robotics have the advantage of creating an environment where learners can develop the 21st century competencies discussed in section 2.2.2. Kayembe and Nel (2019) state that by breaking down complex problems into smaller parts and developing innovative solutions, learners learn to think critically, and to understand how technology can be used to solve problems. Furthermore, I would add Whole Brain® thinking as it informs different aspects mentioned, such as critical thinking – converted to Whole Brain® critical thinking; Whole Brain® problem-solving; Whole Brain® infused innovative solutions. This can be especially useful for learners who may struggle with traditional learning methods, as coding and robotics provide a hands-on, interactive approach to problem-solving (García Peñalvo et al., 2016). Coding and robotics lend themselves to enriched meaning: Whole Brain® coding and robotics.

In addition to Whole Brain® problem-solving competencies, coding and robotics can also encourage Whole Brain® creativity. Kayembe and Nel (2019) and Yang et al. (2020) share the view that a curriculum that includes Whole Brain® enriched technology, especially coding and robotics, can foster learners with Whole Brain® creative thinking abilities. They continue by stating that by offering learners the opportunity to develop innovative solutions to real world problems, coding and robotics can help learners unleash their creative potential and express their ideas in new and exciting ways. This can be particularly beneficial for learners who may not excel in more traditional subjects, such as Mathematics, as coding and robotics provide an outlet for creativity that may not be available in other subjects, such as Natural Sciences (Bers et al., 2014; Bers et al., 2019).

Lathifah et al. (2019) and Bers et al. (2019) state that coding and robotics create an active learning environment where learners and educators are more motivated to interact and collaborate at an interpersonal level during the learning experience. Additionally, this might result in a rise in productivity and skill, both in and outside of the classroom (Kift et al., 2010). According to Jung and Won (2018), this is a crucial facet of education since learners' intrapersonal and interpersonal abilities and values are a basic part of their holistic development.

Coding and robotics can also enhance collaborative problem-solving and verbal communication competencies. Eguchi (2014), Bers et al. (2019) and Lathifah et al. (2019) state that coding and robotics have the advantage of creating an environment where learners can build and develop social and communication competencies through collaborative projects, peer learning and support, presentations and demonstrations and collaborative problem-solving and critical thinking. Learners also develop values such as caring, connection with others, confidence, character and contribution (Bers et al., 2019; Jung & Won, 2018; Latip et al., 2020).

I assert that coding and robotics can aid learners in honing Whole Brain® thinking. Coding and robotics can be effective tools for promoting Whole Brain® learning and thinking. By requiring learners to use a range of competencies and promoting the development of critical thinking, communication, collaboration and social emotional competencies, these tools can help learners become more well-rounded thinkers and problem solvers. Coding and robotics involve a combination of analytical, relational, experimental and practical preferences, stimulating multiple areas of the brain simultaneously.

Analytical components such as coding and robot design engage the analytical attribute of Whole Brain® learning, enhancing critical thinking and problem-solving competencies. The analytical attribute of Whole Brain® learning refers to the left hemisphere of the brain, which is responsible for logical reasoning, analysis, and sequential thinking. Coding involves breaking down complex problems into smaller, manageable components and creating logical sequences of instructions to solve them (García Peñalvo et al., 2016). Robot design requires learners to consider various factors such as functionality, efficiency and effectiveness (Kanbul & Uzunboylu, 2017). They must analyse the requirements of the task or challenge, identify potential limitations or constraints and devise innovative solutions. Thus, coding and robot design, as components of Whole Brain® learning, engage the analytical attribute of the brain, fostering critical thinking, problem-solving competencies and logical reasoning.

Relational cues such as collaboration, peer learning and support and presentation and demonstration engage the relational preference of Whole Brain® thinking, fostering effective communication, social connections and holistic understanding. Collaboration is a key component of coding and robotics activities, requiring learners to work together to achieve a common goal (Kanbul & Uzunboylu, 2017). Engaging in collaborative coding projects or building robots in teams provides opportunities for learners to communicate their ideas, share knowledge and exchange perspectives (Eguchi, 2014). By collaborating with peers, learners engage in dialogue, active listening and negotiation, activating the relational preference of Whole Brain® thinking.

Coding and robotics provide learners with the freedom to express their creativity and imagination (Eguchi, 2014), engaging the experimental preference of Whole Brain® thinking. The experimental preference involves hands-on exploration, creativity and the ability to take risks (Herrmann-Nehdi, 2010). Coding and robotics offer learners a canvas to unleash their creativity and imagination (Education Trends, 2017). In coding, learners can create interactive stories, games, animations and applications, allowing them to express their unique ideas and perspectives (Ellis, 2021). Through robotics, learners have the opportunity to design and build robots that embody their creative vision (Ornstein et al., 2011).

Whole Brain® thinking acknowledges the importance of practical thinking in the learning process (Herrmann-Nehdi, 2010; Palasigue, 2009). Coding and robotics activities embody sequential, organised, detailed and planned aspects (Bers et al., 2019) that engage the practical thinking preference of Whole Brain® thinking – quadrant B. Coding and robotics not only require learners to think sequentially and organise their thoughts in a structured manner (Kanbul & Uzunboylu, 2017), but also demand attention to detail, as learners must carefully analyse and comprehend the requirements of the task at hand (García Peñalvo et al., 2016) and promote systematic problem-solving, where learners approach challenges in a logical and methodical manner (García Peñalvo et al., 2016), which all engage the practical thinking preference of Whole Brain® thinking, referred to as the B quadrant.

By engaging multiple attributes, coding and robotics provide a holistic learning experience, activating and strengthening connections across different areas of the brain.

In conclusion, the fields of coding and robotics have the potential to greatly impact the education system. Coding and robotics offer a wide range of opportunities for learners to develop important competencies such as critical thinking, communication, collaboration and social emotional competencies. By incorporating coding and robotics into the education system, learners can be better prepared for success in the 21st century by using Whole Brain® thinking.

2.2.3.4 Coding and robotics and the impact on practice

Coding involves writing computer programs that tell computers what to do, while robotics is the application of coding to build machines that can perform tasks automatically (Bers et al., 2019; García Peñalvo et al., 2016; The Coding Fun, 2020). The coding and the robotics fields have come together to revolutionise the way we live, work and interact with technology.

With this in mind I advocate for the adoption of a Whole Brain® coding and robotics curriculum. This study includes a closer look into a variety of coding and robotics learning opportunities in which I monitored and studied learner involvement, mastering of coding and robotic competencies and the overall learning process. Such a closer look implies that I, as a practitioner researcher, executed action research in a sequential fashion.

2.2.3.5 Conditions for implementing coding and robotics as a subject

The incorporation of coding and robotics into educational curricula has gained significant importance in the rapidly changing field of technology. In order to succeed in the digital era, it is crucial to provide learners with the necessary opportunities to develop competencies and knowledge needed for this era. This section examines the necessary prerequisites for effectively integrating coding and robotics into educational institutions as a subject.

An essential prerequisite for the successful integration of coding and robotics in educational institutions is the presence of suitable infrastructure and resources. According to El-Hamamsy et al. (2021) and CAPS123 (2023) schools should allocate resources to establish contemporary computer laboratories, furnished with state of the art hardware and software, in order to enhance interactive learning opportunities. Moreover, the availability of robotics kits, coding platforms and other technological tools is essential for establishing a captivating and interactive learning setting (El-Hamamsy et al., 2021; Screpanti et al., 2021).

In order to guarantee the efficacy of coding and robotics programmes, educational institutions must hire skilled instructors who possess a profound comprehension of these disciplines. Screpanti et al. (2021) state that educators should participate in professional development programmes to remain up to date with the latest technological advancements. Magagula and Awodiji (2024) referred to educators being lifelong learners. Yildiz and Seferoglu (2021) explain that it is crucial to prioritise the recruitment of educators who possess a passion for coding and robotics, as their enthusiasm has the potential to ignite inspiration and motivation among learners.

Coding and robotics programmes should be designed to be inclusive, catering to learners of diverse backgrounds, abilities and interests. Educational institutions should strive to create a welcoming environment that encourages all learners, regardless of gender or socio economic status, to participate in coding and robotics activities (Women in digital empowerment, 2020). Díaz-Boladeras, et al. (2023) also explain that efforts should be made to address any potential barriers, such as access to technology, to ensure equal opportunities for all.

Incorporating coding and robotics into the curriculum necessitates a strong framework for ongoing assessment opportunities and evaluation. The Department of Basic Education (2021d) also emphasises that schools should implement assessment strategies that evaluate not only the acquisition of technical expertise but also the cultivation of problem-solving aptitudes, creativity and collaboration. Orrie (2023) explains that consistent input from educators and classmates can provide valuable guidance to learners in their educational progress and assist in improving teaching approaches.

The incorporation of coding and robotics into educational curricula is an essential measure in equipping learners with the necessary competencies to tackle the demands of the 21st century. To effectively implement these subjects, a combination of infrastructure, well trained educators, curriculum integration, inclusive education practices and a strong assessment system is necessary. By fulfilling these criteria, educational institutions can establish a vibrant learning environment that provides learners with the aptitude and expertise required for triumph in a technology-oriented society.

2.2.4 Curriculum

Despite the fact that the general term "curriculum" has different definitions, several authors have attempted to define a curriculum in more detail. In 2018, Booyse and Du Plessis offered a constrained perspective of the term “curriculum”. According to their definition, a curriculum is any plan for guiding learning towards predetermined objectives. According to Dey (2016) a curriculum is a written document implemented in a component of formal instruction with clear objectives. A more comprehensive explanation of what belongs in a curriculum is offered by Brown and Green (2006). Dey (2016) and Brown and Green (2006) claim that in order to be employable, learners need to possess certain competencies. Brown and Green (2006) list these competencies as "critical thinking competencies, problem-solving strategies and effective decision making competencies, creative thinking processes, effective oral and written communication competencies, basic reading, mathematics and writing abilities, knowledge of when and how to use research to solve problems, effective interpersonal competencies, technology competencies, knowledge of wellbeing, acceptance and understanding of diverse cultures and ethnicities and knowledge of technology" (p. 778). The growth of these competencies should therefore be part of the main focus of a curriculum. A curriculum, in its most basic form, outlines what, why and how learners should methodically and consciously learn (UNESCO IBE, 2013). It addresses final objectives, learner experiences, the topic of study and the material covered (Ornstein & Hunkins, 2018). These plans have an impact on the entire process of teaching and learning (Coşkun & Aslan, 2021).

A curriculum, in my view, is in line with the view of Gosper and Ifenthaler (2014). They describe a curriculum as a set of planned learning and teaching experiences that learners and educators encounter with curriculum implementation. Furthermore, informing the curriculum are learners' learning experiences, the goals stated and the results attained (Gosper & Ifenthaler, 2014). Therefore, I assert that a curriculum's main goal is to give learners an organised educational experience while assisting them in developing the information, abilities, values and morals necessary for success in their chosen field of study or career.

2.2.4.1 Curriculum design

Button (2021) defines curriculum design as the process of developing a general framework or structure for a curriculum. Moye (2019) also defines curriculum design as the “blueprint” of a path that learners and educators must follow to reach a set of predetermined goals (p.2). Button (2021) and Moye (2019) state that setting goals and objectives, deciding on the curriculum's scope and sequencing, choosing suitable resources for learning and describing the overall strategy for how the curriculum will be delivered to learners are all part of this process. Male and Waters (2012) argue that curriculum design places significant importance on the overarching framework of knowledge and competencies that learners should develop upon completion of the curriculum.

2.2.4.2 Curriculum development

Although Marzooghi (2016) claims that defining curricular development is a challenging construct, he clarifies that it is a continuous, adaptable process that is relevant to the classroom context in which it is occurring. He continues by saying that, by way of a broad definition, curriculum development may be understood as the planning, carrying out and assessment of a curriculum being used. Curriculum development, according to Booyse and Du Plessis (2018) and Bhuttah et al. (2019), is the challenging process of curriculum reform or innovation. The process of developing a curriculum involves several variables which are discussed in section 2.2.5.

2.2.4.3 Coding and robotics curriculum development in South Africa

a) Need for change

The incorporation of coding and robotics into South Africa's education system represents a significant advancement into the digital era, recognising the need to provide the country's youth with vital competencies to navigate the intricacies of the modern world. This section explores the various reasons behind the integration of coding and robotics into the South African educational system.

In the context of a growing global economy, countries are involved in a competition that goes beyond traditional measures of natural resource availability, including the development of intellectual knowledge and competencies (United Nations Conference on Trade and Development, 2020). Countries that strategically invest in technological literacy gain a unique competitive advantage by recognising and adapting to this significant change in thinking (United Nations Conference on Trade and Development, 2020). In order to prepare its youth for a future that is increasingly shaped by technological progress, South Africa has made a strategic decision to incorporate coding and robotics into early education (Magwentshu & Rajagopaul, 2019).

The United Nations developed a set of Sustainable Development Goals. Goal 4 or the Quality Education goal promotes “inclusive and equitable quality education” and “lifelong learning opportunities” (United Nations, 2015). In accordance with this goal, the South African Government (2020) published a white paper, the *National Digital and Future Competencies Strategy* that aims to develop South Africans’ digital competencies. In alignment with this white paper, the Department of Basic Education developed a digital competencies curriculum that proposes coding and robotics as an official subject (Writer, 2020).

The digital divide persists as a widespread social issue, perpetuating inequalities, especially among marginalised communities in terms of technology access and digital literacy (Greyling, 2022). According to Veldman et al. (2021) the digital divide refers to inequalities in access to Information and Communications Technology (ICT) or digital exclusion and lack of material resources. South Africa's intentional incorporation of coding and robotics into its educational system demonstrates a strategic dedication to improving this division (Magwentshu & Rajagopaul, 2019). Nkosi (2023) explains that the objective of this pedagogical approach is to establish a setting in which all learners, regardless of their background, have equal opportunities to develop crucial digital competencies.

Integrating coding into education is crucial for developing 21st century competencies (discussed in section 2.2.2). Robotics education simultaneously fosters collaboration, design thinking, and experiential learning, which are all essential 21st century competencies necessary for future job prospects (Barbazzeni, 2021; Nkosi, 2023).

Coding and robotics serve as catalysts, enabling learners to unlock their innovative abilities and fostering a mindset that is conducive to entrepreneurship. South Africa's strategic focus on developing these competencies highlights a desire to mould a generation that is capable of generating job opportunities instead of solely pursuing employment (Freese, 2021; Greyling, 2022). This intentional emphasis establishes the groundwork for a strong technological environment that promotes long term economic expansion (Academy of Science of South Africa, 2021).

The field of technology offers a wide range of career options that go beyond traditional software development (Greyling, 2022). These include areas such as data science, cybersecurity, automation engineering and game design (Bouchrika, 2023). Greyling (2022) states that by incorporating coding and robotics into the educational system, South Africa's young population is empowered to explore a wide range of professional paths, thus making a significant contribution to the overall development of the nation.

To summarise, South Africa's deliberate incorporation of coding and robotics into its educational system demonstrates a progressive approach to meet the requirements of a globalised, technology driven economy. This initiative focuses on key components such as worldwide competitiveness, bridging the gap in digital access and fostering essential competencies for the 21st century, such as critical thinking and creativity. South Africa positions itself as an active participant in shaping a technologically empowered future by prioritising innovation and entrepreneurship, diversifying career options, making knowledge accessible to all and preparing education for the Fourth Industrial Revolution. This transformative journey exemplifies the nation's dedication to inclusivity, the active engagement of citizens, and the comprehensive growth of its young population. It establishes coding and robotics as more than just subjects, but as indispensable instruments for navigating and making valuable contributions to the ever-changing global environment.

b) Curriculum development timeline

The coding and robotics curriculum development took place in 2019 and concluded in 2020 (DBE, 2021a, b). According to Fares et al. (2021) and the Department of Basic Education (2021b), this curriculum aims to equip Grade R – 3 learners with the basics of coding and algorithms. They further explain that Grade 4 – 6 will learn to use block-based programming tools such as Scratch and lastly, Grades 7 – 9 learners will use "line-based coding platforms", which include more rigorous programming and robotic competencies.

Jonathan Freese, from the Department of Basic Education, presented a timeline for the implementation of coding and robotics at the "The Status of Coding and Robotics in South African Schools", Webinar hosted in 2021 (Veldman et al., 2021). In this timeline, he states that the curriculum development planning began in 2017 (Veldman et al., 2021). Thereafter President Ramaphosa announced the expansion of the current curriculum, known as the Curriculum Assessment Policy Statements (CAPS) to include the technology subject in 2019 (South African Government, 2019). During 2019 the Department of Basic Education identified many pilot schools including 200 Grade R – 3 schools and 1000 Grade 7 schools (Veldman et al., 2021; Writer, 2020). Coding and robotics were developed into a stand-alone subject from Grade R – 9 in 2020, and the proposed curriculum was submitted for approval to the statutory body in South Africa called UMALUSI in charge of ensuring the quality of education and training (Veldman et al., 2021). In 2021 the curriculum was approved, and the orientation of Provincial Task Teams and Pilot educators began (Veldman et al., 2021). The Department of Basic Education first wanted to start implementation in 2020 (DBE, 2021c), starting with Grade R – 3 during 2020 and Grades 4 – 6 during 2021 (DBE, 2021c). The piloting process for Grades 7 – 9 should have taken place in 2022 (DBE, 2021c). However, the proposed amendments to the CAPS to include coding and robotics were only approved and published in 2021 (Veldman et al., 2021). According to the Department of Basic Education (2021a, c), this backlog of implementation is due to the Covid-19 pandemic and the piloting periods were from 2021 to 2023. The Department of Basic Education was planning to implement the new curriculum as follows: In 2021 the programme should have been introduced in the Foundation Phase and Grade 7, in 2022 in Grade 8, in 2023 in Grade 9 and finally, in 2024 the subject would be compulsory as a stand-alone subject for Grade R–9 (Veldman et al., 2021). However, the Department has announced the annual performance plan 2022/2023, and according to Adewusi (2020) and Mathopo (2022) it outlines the full implementation for Grade R – 3, and Grade 7 that took place in the 2023 academic year. The 2024 academic year is scheduled for the complete implementation of the programme for learners in Grades 4 – 6 and Grade 8 (Liebenberg, 2023). The 9th Graders will follow suit in the academic year of 2025 (Liebenberg, 2023).

Furthermore, Robotics Education South Africa (RESA) and RoboCup Junior South Africa have been actively engaged in advancing the cause of robotics education in schools throughout the country (CAPS123, 2023). Both organisations host robotics competitions that provide learners with the opportunity to demonstrate their competencies while enhancing their problem-solving and critical thinking capabilities.

c) Challenges for implementation in SA

Reports such as the report by The African EdTech Insights presents a thorough examination of South Africa's initiatives in implementing the coding and robotics curriculum (Malinga, 2023; Mathopo, 2022). Although they report progress, they have identified multiple challenges for the implementation of coding and robotics in South African schools. The main challenges include educator competencies and training (Tzagkaraki et al., 2021; Veldman et al., 2021), educators' willingness to adopt coding and robotics into their teaching practice (Camilleri, 2017) access to technology in classrooms (Liebenberg, 2023; Veldman et al., 2021), and the financial barriers to implementation of coding and robotics (Liebenberg, 2023).

The first challenge, as emphasised by Veldman et al. (2021) and CAPS123 (2023), pertains to the scarcity of skilled educators in South Africa and the inadequate competencies among current educators. There is also a decrease in the number of computer educators graduating from higher education institutions, and many of them lack previous experience with relevant programmes (Lathifah et al., 2019). Fares et al. (2021) highlight the lack of substantial skill development programmes, which impede educators from acquiring the essential competencies for effectively teaching coding and robotics. The insufficiency is worsened by a scarcity of available and reasonably priced opportunities for professional growth, as highlighted by García-Carrillo et al. (2021) and Wong et al. (2015). According to the scholarly work of Tyler (2022) and the Academy of Science of South Africa (2021), there is a prevailing perception that educator training programmes are frequently deemed ineffective. This ineffectiveness is attributed to their excessive technical focus, which fails to offer sufficient guidance for integrating the acquired knowledge into existing curricula. Furthermore, the absence of hands-on practical experience for educators hampers their effectiveness in the classroom (Academy of Science of South Africa, 2021; Tyler, 2022). This also leads to challenges with the integration of the subject into teaching practice.

Secondly, the incorporation of coding and robotics into methods of facilitating learning poses a challenge, as educators find it difficult to keep up with the rapid technological progress. According to Camilleri (2017) and Papadakis et al. (2021), educators demonstrate a sluggish inclination to adopt new technologies, frequently adhering to obsolete teaching methods. It is essential to overcome this resistance and promote a more progressive approach to teaching methodologies to effectively introduce coding and robotics in South African classrooms.

Thirdly, Kayembe and Nel (2019) mention that inequality in access to resources and the digital divide is a big problem in South Africa. This digital divide creates inequality in South African education (Veldman et al., 2021). Kayembe and Nel (2019), Fares et al. (2021), Ellis (2021) and Mathopo (2022) agree that many learners and schools do not have access to computers or the funds to acquire technology. Without access to computers or the financial resources, it is impossible to create an environment for learners and educators to develop their coding and robotics competencies effectively.

Lastly, many schools lack the finances to implement technology into the schools (Fares et al., 2021). A major obstacle lies in the insufficient funding designated for the incorporation of coding and robotics into the national curriculum (Freese, 2021). According to CAPS123 (2023) the majority of schools do not possess the necessary resources to acquire essential equipment, software and employ experts to teach various subjects. The Academy of Science of South Africa (2021) states that the insufficient budget allocated for technological progress in schools poses a substantial obstacle to the introduction of coding and robotics subjects.

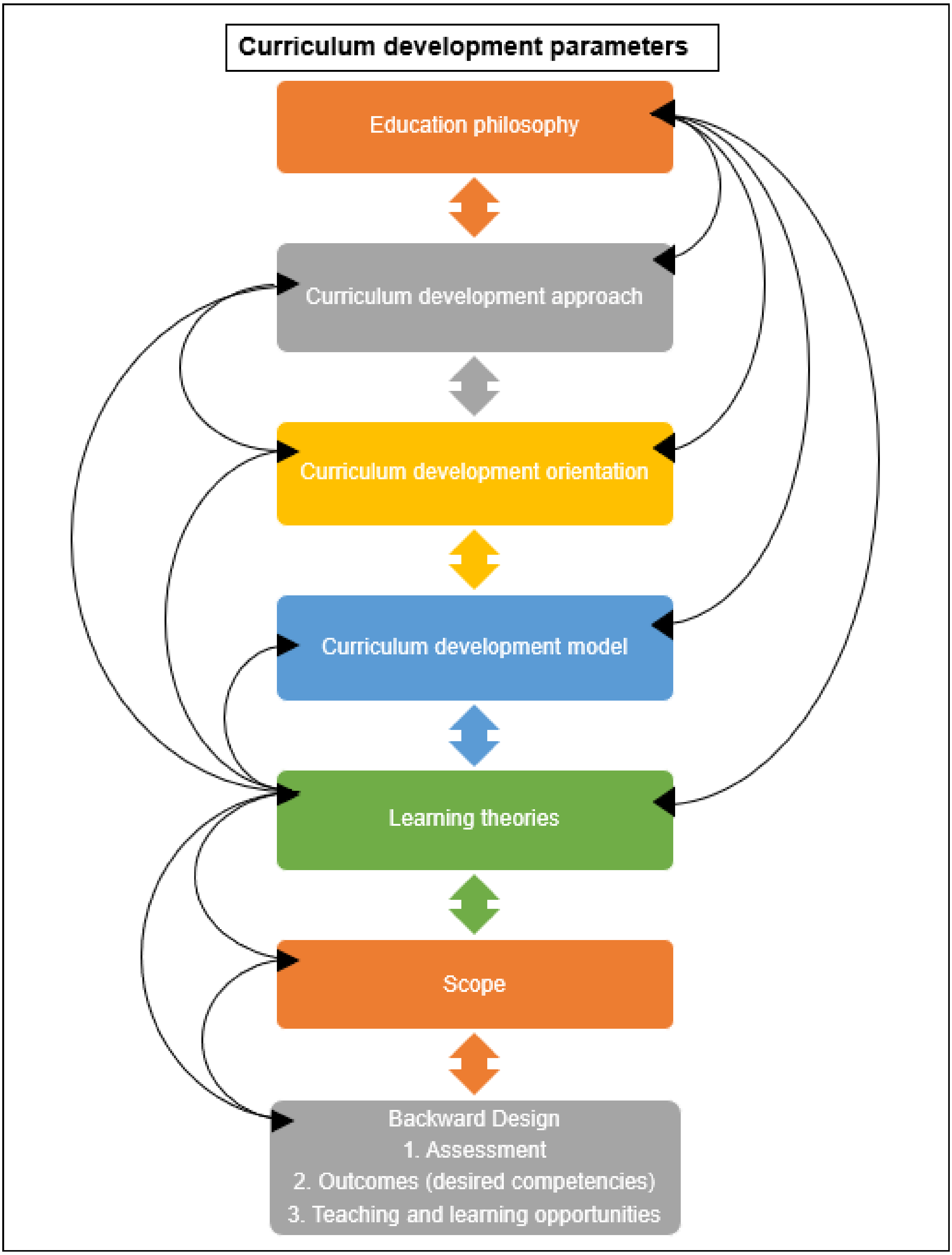
In conclusion, the prospects for successfully implementing coding and robotics in South African schools are impeded by a range of challenges. To overcome these challenges, it is necessary to adopt a comprehensive approach that focuses on enhancing skill development, promoting a change in methods of facilitating learning, addressing the digital gap and offering greater financial assistance. This will ensure a fair and efficient implementation of coding and robotics education in South African schools.

2.2.5 Process of designing and developing a curriculum

The process of designing and developing a curriculum involves several variables, including an education philosophy, curriculum development approach, curriculum development orientation, curriculum development models, learning theories, a curriculum scope, assessment opportunities, desired competencies (outcomes), and the learning and teaching opportunities (Button, 2021; Carl, 2009, 2017). Other factors include curriculum creation philosophy, method, orientation, models and learning theories (Carl, 2009, 2017). Figure 5 provides an illustration of this process.

Figure 5

Curriculum development variables



2.2.5.1 Education philosophy

Philosophy in education refers to a body of ideas and convictions about the nature of knowledge, the purposes of education, and the goals of education that influence what should be done to achieve the goals and how the learning environment is arranged (Endeley & Zama, 2021; Ornstein et al., 2011).

Curriculum design process makes use of progressivism. According to Hewitt (2006) and Tippett and Lee (2019), progressivism emphasises the importance of learning through experience. In short, progressives believe that learners learn best when they are actively engaged in the learning process and when they are given the opportunity to explore and discover new things on their own. As a result, progressive education often involves hands-on, experiential learning activities, rather than traditional lecturing and rote memorisation. Therefore, this philosophy is concerned with the learner rather than the content or educator (Endeley & Zama, 2021). Hewitt (2006) explains that the learner's abilities will influence the curriculum content, with tailor made teaching. Ornstein and Hunkins (2018) state that the ideas of this philosophy aim to look at individuals as a whole. Learners must get opportunities to resolve learning situations, answer things here and now and reflect on real-life situations, making it a reciprocal learning environment, where both educators and learners learn (Ornstein & Hunkins, 2018) to prepare learners for participation in society (Tan et al., 2006).

The philosophy is influenced by, and in turn influences the approach, orientation, curriculum development model and learning theory. Based on the chosen philosophy, it is evident that the approach, orientation, curriculum development model and learning theory should enable learners to build their knowledge through practical exercises in their surroundings while applying and reflecting on actual experiences.

2.2.5.2 Curriculum development approach

A curriculum development approach is a way of thinking about the design of the curriculum (Ornstein et al., 2011). Ornstein and Hunkins (2018) divided curriculum development approaches into technical and non-technical approaches. Bhuttah et al. (2019) explained that the technical scientific method of imparting education is regarded as logical, effective and efficient, focusing on the content and outcomes, whereas the non-technical, which emphasises the learner, is described as subjective, individual and aesthetic, with focus on the learning experience. I applied the pragmatic approach, a non-technical approach to curriculum building. In addition to the pragmatic approach, I employed the Whole Brain® approach, which uses the principles of Whole Brain® thinking to inform the curriculum design process.

I argued that the integration of the Whole Brain® approach into curriculum development offers a comprehensive framework that encompasses both technical and non-technical aspects. This approach functions on two separate levels. Firstly, it utilises Whole Brain® thinking to create and implement the curriculum, acknowledging and utilising the various cognitive functions found in each person (Herrmann, 1999). This entails integrating analytical, pragmatic, interpersonal and exploratory thinking modes, guaranteeing that the curriculum fully engages learners. Furthermore, the Whole Brain® approach utilises the principles of Whole Brain® thinking to guide different components of the curriculum, such as learning opportunities, assessment opportunities and desired learning outcomes. By doing so, it guarantees that the curriculum is in line with a learner centred, subjective and aesthetic approach, as advocated by Bhuttah et al. (2019) in non-technical methods of curriculum development. This approach promotes a more comprehensive and efficient educational setting by accommodating the varied cognitive preferences and strengths of learners.

The pragmatic approach, characterised by its emphasis on practicality and effectiveness (Rai & Lama, 2020), is perfectly compatible with the Whole Brain® approach. According to Rai and Lama (2020) and Hewitt (2006), pragmatism emphasises lived experiences and understanding the learner's own environment. The innovative Whole Brain® approach acknowledges the diverse cognitive functions within each individual, encompassing analytical, practical, relational and experimental thinking modes (Herrmann, 1999). Both approaches place importance on the learner's experience and surroundings, highlighting the necessity of a curriculum that is both efficient and pertinent, while also captivating. By integrating the pragmatic approach with the Whole Brain® approach, the process of curriculum development becomes a dynamic and interactive expedition, influenced by the changing needs and objectives of both learners and educators.

The selected philosophy and learning theory, which prioritise the construction of knowledge from one's environment, are closely aligned with the Whole Brain® approach. The emphasis on the learner's experience and cognitive diversity guarantees that the curriculum is not only based on solid educational principles but also tailored to accommodate the diverse range of cognitive abilities in each person. Consequently, the process of developing the curriculum becomes a dynamic and inclusive undertaking, ultimately resulting in a more effective and enriching educational experience for all learners.

The curriculum development orientation (discussed in section 2.2.5.3), learning theory and philosophy have a direct influence on the curriculum development approach. According to the chosen philosophy and learning theory, learning must occur by constructing knowledge (learning theory) of the environment around them (philosophy), meaning that the environment and situation are at the centre.

2.2.5.3 Curriculum development orientation

Alsalem (2018) defined a curriculum development orientation as an educators' beliefs about the goal of the curriculum and education. Each orientation has a distinct view on virtues, norms, values and attitudes that must be included in the final curriculum (Carl, 2009). In this study, the curriculum is based on the cognitive orientation to curriculum development.

The cognitive orientation emphasises the mental processes involved in learning and the importance of understanding how learners think and learn. According to Alsalem (2018) this orientation focuses on the learning process rather than content. He continued to explain that this orientation requires educators to facilitate the learning process to help learners learn how to solve problems, ask questions and think critically.

The orientation of curriculum development influences the philosophy, curriculum development approach and learning theory. In turn, philosophy, curriculum development approach and learning theory also have a direct influence on the curriculum development orientation. Again, learners must construct their own knowledge (learning theory) in the world they live in (approach and philosophy).

2.2.5.4 Curriculum development models

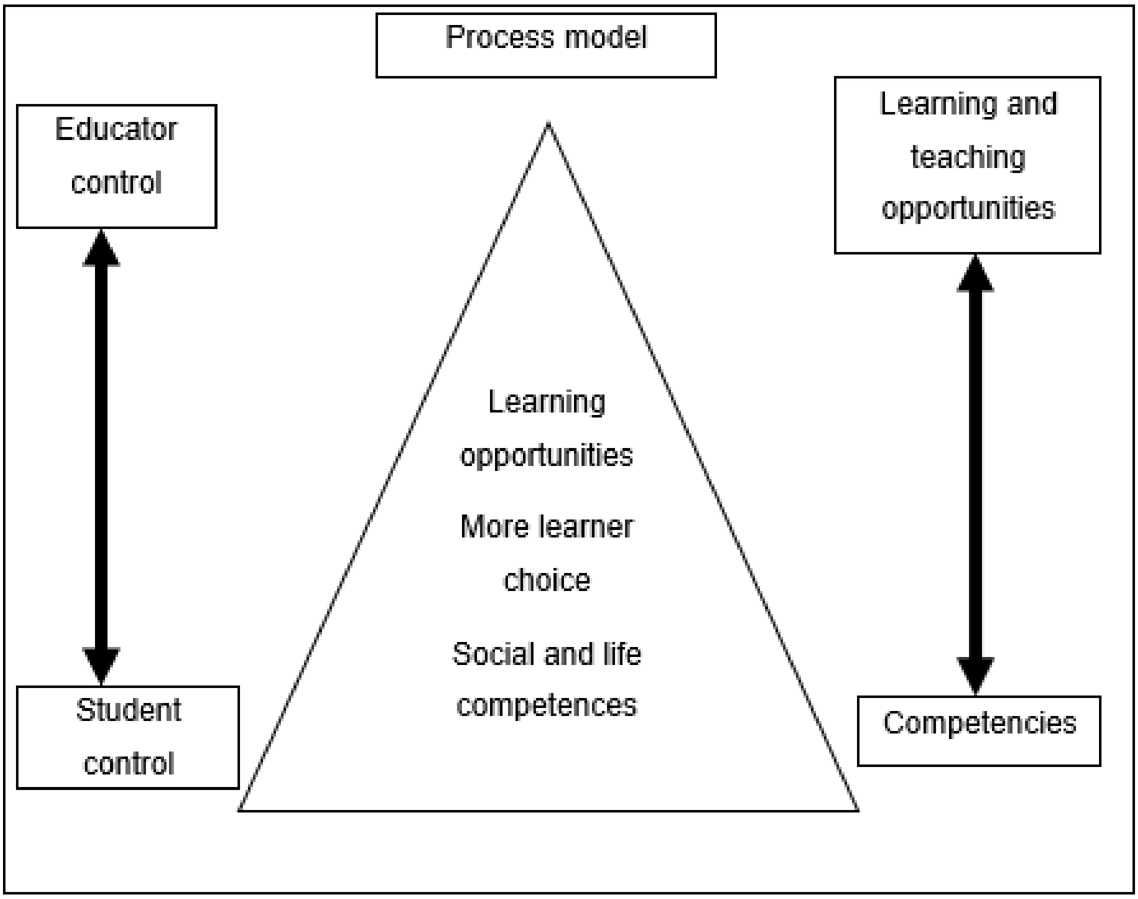
Curriculum models are broad theoretical frameworks used as a basis to design and organise the curriculum (UNESCO IBE, 2013). These models assist curriculum developers by guiding planners, mentors and administrators in the process (Bhuttah et al., 2019). There are many models to aid in curriculum development, such as the Tyler model (1949), Stenhouse model (1975), Taba inductive model (1966), etcetera. This study utilises the Process Model developed by Lawrence Stenhouse in 1975.

This model was first presented by Lawrence Stenhouse in his foundational work, *An Introduction to Curriculum Research and Development*, published in 1975. Despite the fact that this construct was first proposed many years ago, it is still applicable today. Many researchers and curriculum developers still use this model in their arguments when developing a curriculum, such as Hotham (2021), McLaughlin and Wood (2021), and Elliott (2019).

The process model of curriculum development emphasises developing the curriculum rather than the final product. Stenhouse argued that curriculum development should be a process (Marzooghi, 2016; O'Neill, 2015; O'Neill & Murphy, 2010) and the focus of a curriculum should be on the learning tasks and methods (Bhuttah et al., 2019). The idea of curriculum as a process is one in which variables such as context and participants cannot be predicted in advance and should therefore be adaptable (Booyse & Du Plessis, 2018). This is seen from the fact that many curriculum developers still utilise this approach, which was introduced in 1975. This model further emphasises learning acquired from lived experience. Figure 6 demonstrates how a learner centred model emerges when learners have greater control over their educational experiences, which results in more meaningful learning activities, learner choice and social and life competencies (O'Neill & Murphy, 2010).

Figure 6

Process model illustration (adapted from O'Neill, 2015)



This curriculum development model influences all of the parameters mentioned in Figure 5. The model is also influenced by all parameters.

In my curriculum development process, I've adapted the process model by focusing on learning and teaching opportunities rather than just content. This approach aligns with constructivism, emphasising the active role of learners in constructing their understanding. Additionally, I refer to competencies rather than skills, highlighting the broader abilities and capacities that learners develop through the curriculum.

2.2.5.5 Learning theories and multiple intelligences

It is an attempt to define how learners learn. According to Endeley and Zama (2021) there are many factors that influence how learners learn, such as their personality, culture and prior knowledge. Illeris (2018) and Endeley and Zama (2021) explain that a learning theory aims to explain how learners gain, retain and recall knowledge. The learning theory used in this curriculum is the Whole Brain® learning model and multiple intelligences.

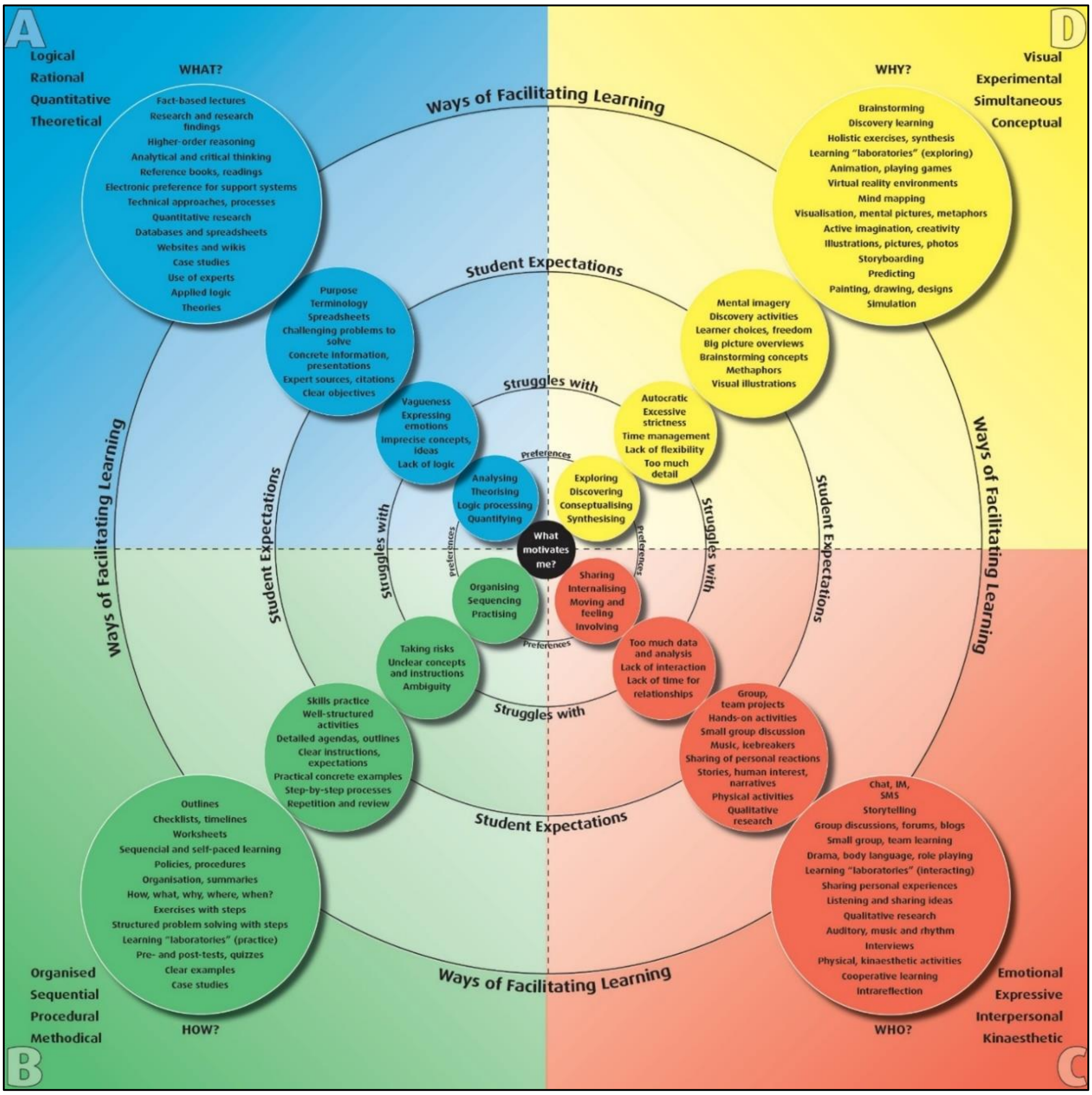
a) Whole Brain® learning

Whole Brain® learning is a teaching approach that aims to engage all parts of the brain in the learning process. Many researchers explained that in order to assist learners to learn in a method that is most conducive to their particular learning preferences, it places an emphasis on the utilisation of a range of learning modes, including visual, auditory, reading, writing and kinaesthetic (De Boer et al., 2001; De Boer et al., 2015; Deshpande, 2010; Herrmann-Nehdi, 2010; Herrmann Global LLC, 2022).

The "Whole Brain® Model," which Dr. Ned Herrmann, created as an approach to brain function and learning preferences, serves as the foundation for the Whole Brain® learning model (De Boer et al., 2001; Herrmann Global LLC, 2022). This model suggests that the brain is divided into four quadrants, each of which corresponds to a distinct thinking preference. These four quadrants are illustrated in Figure 7 and discussed below.

Figure 7

Comprehensive Whole Brain® thinking model (De Boer et al., 2013)



The left hemisphere is predominant in people who learn best visually and is linked to logical, analytical and linguistic thinking (De Boer et al., 2013; Herrmann-Nehdi, 2010; Herrmann, 1995). The right hemisphere, which is predominant in people who learn best by hearing, is linked to creative, intuitive and spatial thinking (De Boer et al., 2013; Herrmann-Nehdi, 2010; Herrmann, 1995). The top region of the brain is important for reading and writing abilities and predominant in people who learn best through reading and writing (De Boer et al., 2013; Herrmann-Nehdi, 2010; Herrmann, 1995). The bottom region of the brain is predominant in people who learn best through kinaesthetic or hands-on methods (De Boer et al., 2013; Herrmann-Nehdi, 2010; Herrmann, 1995).

Furthermore, there are unique cognitive function clusters in each quarter. Dlamini (2020), and De Boer et al., (2001) explain that a person who prefers the A quadrant favours pursuits that need logic, analysis and fact-based information. Learners that think in this way also favour logical thought, require data and facts, generate examples and hypotheses, and respond well to formal lectures, group discussions, textbooks and structured learning (Oosthuizen, 2007). A person who prefers the B quadrant has a linear approach to activities. People with a preference for the B quadrant value ordered, sequential, planned and thorough information. In addition to preferring testing ideas, these learners appreciate structure and process, are focused on developing competencies via practice, and respond favourably to lectures, textbooks, conversations and other structured, sequential formats (Oosthuizen, 2007). A preference for the C quadrant implies a desire for interpersonal, feeling-based and emotionally charged information (De Boer et al., 2001; Dlamini, 2020; Le Roux, 2011). This type of learner appreciates intuitive thinking, strives for harmony, enjoys integrating lived experiences with oneself, and responds well to hands-on, sensory engaged activities, movement, music, cases that are focused on people and group interaction (Oosthuizen, 2007). Preference for the D quadrant is mostly indicated by a constructive and comprehensive and often creative way of thinking (De Boer et al., 2001; Dlamini, 2020; Le Roux, 2011). Individualised, immersive, experimental, visually appealing and aesthetic learning designs are well received by learners with this type of thinking preference seeing that they value self-discovery, construct concepts, value intuition and are concerned with hidden possibilities (Oosthuizen, 2007).

Individuals favour one of these learning preferences, while they may also employ other forms to a lesser amount, according to the Whole Brain® learning model (De Boer et al., 2001). Identification of a person's primary thinking preference and subsequent adaptation of learning opportunities to that preference are key components of Whole Brain® learning, which aims to improve learning and retention.

b) Multiple intelligences

The notion of intelligence has been a topic of great interest and investigation, with conventional perspectives often emphasising a solitary assessment of cognitive aptitude (Gardner, 1987). Howard Gardner's Theory of Multiple Intelligences, presented in his influential work, challenges the traditional view by suggesting that intelligence is not a single entity, but rather a varied collection of abilities (Gardner, 1987). Gardner's theory, initially presented in 1987, posits that individuals possess multiple intelligences, each representing a distinct approach to information processing and problem-solving (Chongde & Tsingan, 2003). White (2005) states that Howard Gardner's Theory of Multiple Intelligences, which was originally presented with six separate dimensions, has since developed to include a more extensive comprehension of human cognitive capabilities. Initially eight intelligences were identified, each signifying a distinct manner in which individuals assimilate information and interact with the world, namely linguistic, logical-mathematical, spatial, bodily-kinaesthetic, musical, interpersonal, intrapersonal and naturalistic (Gardner, 2021; Rasheed & Wahid, 2021; White, 2005). Recently a ninth intelligence, namely existential intelligence was added to the list.

Linguistic intelligence, as explained by Gardner (2015), refers to a strong ability in language related tasks such as reading, writing and verbal communication. Individuals possessing this cognitive ability demonstrate exceptional proficiency in analysing information, constructing persuasive arguments, and skilfully employing language to accomplish predetermined goals (Gardner, 2015; White, 2005).

Logical-mathematical intelligence, according to Gardner (1987), refers to the ability to systematically analyse problems and apply mathematical principles to solve abstract problems. Individuals with this intelligence exhibit exceptional aptitude in critical thinking, problem-solving and mathematical reasoning (Chongde & Tsingan, 2003; Nolen, 2003).

Spatial intelligence, as defined by Gardner (1987), pertains to the capacity to proficiently employ visual tools for problem-solving purposes. Individuals possessing this cognitive aptitude demonstrate remarkable skill in tasks requiring spatial reasoning, visualisation and manipulation of visual elements (Cavas & Cavas, 2020; Gardner, 2015).

According to Gardner (1987), bodily-kinaesthetic intelligence, refers to the capacity to proficiently employ the entire body and execute skilled movements to overcome obstacles. Individuals possessing this form of intelligence typically exhibit exceptional aptitude in tasks requiring precise physical coordination, dexterity and mastery of bodily movements (Davis et al., 2011; Gardner, 2015).

Musical intelligence, as defined by Gardner (1987), pertains to the ability to generate and assess pitch, rhythm and sound. Individuals with this cognitive ability may exhibit exceptional proficiency in composing, performing or appreciating music (Davis et al., 2011; Gardner, 2015).

Interpersonal intelligence, as defined by Gardner (1987), pertains to the capacity to discern and explore the intentions, emotions and desires of other individuals. Individuals possessing this intelligence exhibit remarkable aptitude in social interactions, communication and understanding the complexities of interpersonal relationships (Cavas & Cavas, 2020; Nolen, 2003).

Intrapersonal intelligence, as defined by Gardner (1987), pertains to the ability to possess a thorough comprehension of oneself and adeptly regulate one's own life and emotions. Individuals with this intelligence exhibit self-awareness, introspection and skill in regulating their own thoughts and emotions (Chongde & Tsingan, 2003; Nolen, 2003).

The concept of naturalistic intelligence, as defined by Gardner (2015), pertains to the capacity to recognise and classify various plant and environmental species within one's immediate surroundings. People who possess this intelligence often show a deep interest in nature, ecology and the complex patterns of the environment (Cavas & Cavas, 2020; Nolen, 2003).

Existential intelligence encompasses an ability to delve into deeper questions about life and existence. People with this type of intelligence contemplate the "big" questions about topics such as the meaning of life and how actions can serve larger goals.

In embracing this diversified perspective on intelligence, Gardner's Theory of Multiple Intelligences provides educators, researchers and individuals with a framework that fosters a more inclusive and holistic approach to understanding and developing human potential. The acknowledgment of these varied intelligences contributes to a richer comprehension of human diversity and underscores the importance of nurturing and celebrating the multifaceted nature of intelligence.

c) *Discussion on aligning Multiple Intelligences and the Whole Brain® learning model*

The Whole Brain® learning model, based on Dr. Ned Herrmann's Comprehensive Whole Brain® thinking model, offers a framework that goes beyond conventional learning theories (Herrmann, 1995). The assertion not only recognises the various cognitive functions present in the brain, but also incorporates the idea of multiple intelligences, acknowledging that learners have specific preferences for how they acquire and process information (De Boer et al., 2015). In the context of Whole Brain® learning, the four quadrants of the brain represent unique thinking preferences, each aligned with specific cognitive functions (Herrmann-Nehdi, 2010). This aligns with the idea of multiple intelligences, as proposed by Howard Gardner, which suggests that individuals possess different intellectual strengths or capacities (De Boer et al., 2015).

The left hemisphere, which is linked to logical and analytical thinking, appeals to individuals who have a preference for visual learning and prioritise linguistic and analytical intelligences (Corballis, 2014; Guy-Evans , 2023). Conversely, the right hemisphere, which is associated with creative and spatial cognition, supports individuals who excel in auditory learning and possess creative and spatial intelligences (Griggs , 2010; Guy-Evans, 2023). The superior area, which is essential for the processes of reading and writing, attracts individuals who possess a predisposition towards linguistic intelligence (Corballis, 2014; Guy-Evans, 2023). Finally, the lower area, associated with kinaesthetic or tactile learning, caters to individuals who excel in bodily kinaesthetic intelligence.

Furthermore, the examination of cognitive function clusters within each quadrant is consistent with Gardner's theory of multiple intelligences. Herrmann (2010) states that individuals who prefer the A quadrant, which focuses on logic and analysis, display traits that are consistent with logical-mathematical intelligence. Herrmann (2010) elaborates that individuals who prefer the B quadrant, which involves valuing organised and sequential information, exhibit traits that align with logical-mathematical and potentially intrapersonal intelligences. Herrmann (2018) subsequently elucidated that the C quadrant, which places significant emphasis on interpersonal and emotionally charged information, closely corresponds to Gardner's interpersonal and intrapersonal intelligences. Learners who demonstrate a preference for the D quadrant, which is characterised by analytical and holistic thinking, align with traits linked to spatial and intrapersonal intelligences (Herrmann, 1995).

The Whole Brain® learning model effectively integrates the principles of multiple intelligences, offering a comprehensive approach to comprehending and accommodating the various ways in which learners interact with and absorb information. The Whole Brain® learning model promotes the identification of an individual's primary thinking preferences, which is in line with the principles of adjusting learning opportunities to cater to different intelligences. This approach improves the overall learning experience and retention for a wide range of learners.

2.2.5.6 The scope of the curriculum

The scope of a curriculum refers to the curriculum’s learning and teaching experiences, and the organisation of these learning and teaching experiences (Endeley & Zama, 2021; Ornstein & Hunkins, 2018). Brown and Green (2006) reiterate this definition, pointing out that scope includes all education experiences designed to get learners interested in learning.

2.2.5.7 Backward design

Ornstein and Hunkins (2018), Emory (2014) and Wiggins and McTighe (2005) describe backward design as a strategy to analyse learning experiences by starting at the desired results, achievements or experiences, working backwards by choosing the assessment opportunities needed to measure whether the desired results, achievements or experiences were met, then the desired results and lastly, the content, or experiences needed to meet the desired results (as illustrated in Figure 2). According to Knowledge Base (2021) and Wiggins and McTighe (2005) educators can create an aligned course or learning opportunities by using the backward design approach as part of the course design process. When Knowledge Base (2021) says that the activities, content and assessment opportunities are aligned, they mean that learning and teaching experiences will support learners in achieving the desired results, achievements or experiences.

a) *Outcomes/desired competencies and learning experiences (aims and objectives)*

Outcomes of learning opportunities can be seen as the aims and objectives of these learning opportunities. Wiggins and McTighe (2005) explain that the outcomes refer to the desired achievements or experiences as part of learning opportunities or a course. Typically, outcomes are established based on the principles of SMART outcomes and Bloom's revised taxonomy, as outlined by Bloom (2010) and depicted in Figure 8. Both these theories are discussed in more detail below.

SMART outcomes

Many academics promoted the idea of defined and measurable goals between the 1940s and 1950s (Howard, 2007; Morrison, 2022). Lawlor and Hornyak (2012) and Morrison (2022) went on to say that these authors also began to make reference to meaningful and realistic outcomes. These outcomes led to the development of the acronym SMART. Gerani et al., (2020) and Lawlor and Hornyak (2012) argue that these results need to be specified, measurable, attainable and time bound (SMART). Specific outcomes specify precisely what is required of a learner (Lawlor & Hornyak, 2012). Measurable outcomes refer to the methods used to gauge an outcome (Chatterjee & Corral, 2017). They added that the precise magnitude of the anticipated change should be quantified in the results. Results that might be achieved are referred to as attainable outcomes (Lawlor & Hornyak, 2012). These outcomes, according to Chatterjee and Corral (2017), are those that can be accomplished in the allotted time and with the available resources. Results that are in line with teaching strategies and evaluation criteria are referred to as relevant results (Chatterjee & Corral, 2017). Results that can be achieved in a timely manner are referred to as time bound outcomes (Lawlor & Hornyak, 2012). These goals should also specify a deadline by which the goal shall be accomplished (Chatterjee & Corral, 2017).

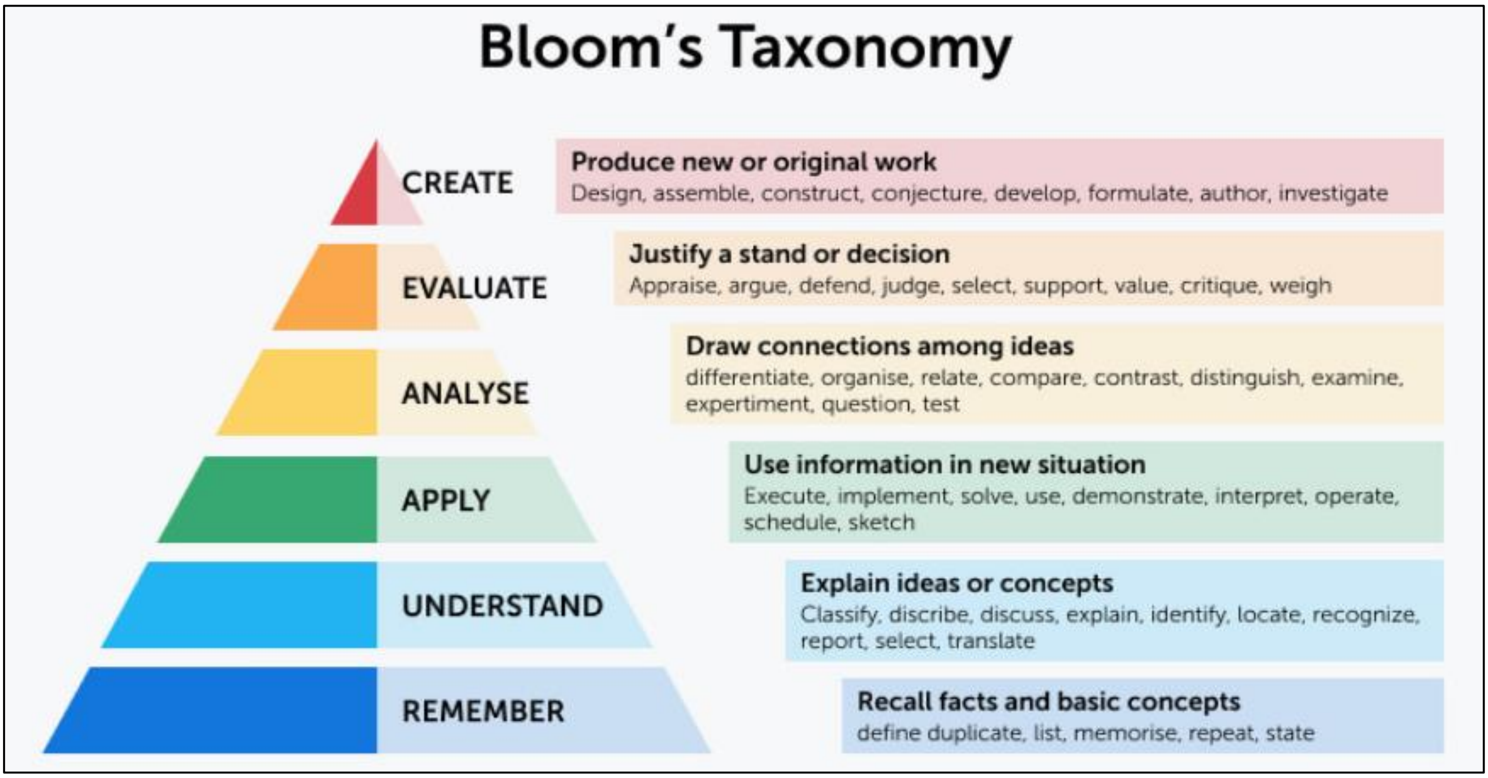
Bloom’s Revised Taxonomy

Bloom developed a taxonomy of educational objectives in 1956 to encourage higher levels of thinking in the classroom (Endeley & Zama, 2021). Bloom's Taxonomy makes an effort to categorise the many stages of learning, from recalling facts to coming up with new ideas based on the learned experiences (Chatterjee & Corral, 2017). In short, according to Bloom's Taxonomy, learning is a sequential process. Learners must understand a concept before using it in the real world (Sobral, 2021; Valamis, 2022). Valamis (2022) further explained that learners need to keep in mind the essential details of a concept before they can understand it. According to this taxonomy, thinking can be divided into the following categories: knowledge, comprehension, application, analysis, synthesis and evaluation (Wilson, 2016). Researchers such as Wilson (2016), Chatterjee and Corral (2017), Sobral (2021) Valamis (2022) explain that the knowledge level refers to retrieving or recalling previously taught information. They further state that comprehension refers to the learners' capacity to understand or derive meaning from content. application is the ability to apply knowledge or to put it into practice in real world circumstances (Chatterjee & Corral, 2017; Sobral, 2021; Valamis, 2022; Wilson, 2016). They also define analysis as the learners' ability to break down material into their constituents in order to better understand its organisational structure. According to them, synthesis refers to the capacity to combine components to create a coherent or distinctive new whole. Lastly, evaluation refers to the capacity to assess, verify, and even criticise a material's suitability for a certain purpose (Chatterjee & Corral, 2017; Sobral, 2021; Valamis, 2022; Wilson, 2016).

This framework was revised by Anderson and Krathwohl in the 1990's to 2001 to include an additional level of cognitive competencies referred to as "creation" (as illustrated in Figure 8) (Anderson & Krathwohl, 2001). According to Wilson (2016) neither the listing or rewording of nouns to verbs, the renaming of some of the components, or even the repositioning of the last two categories are the main alterations. The taxonomy's more complete and valuable additions regarding how it interacts with other sorts and degrees of knowledge, including factual, conceptual, procedural and metacognitive knowledge, are where the main differences lie. To illustrate how one is instructing at both the knowledge and cognitive process levels, this blending can be charted.

Figure 8

Bloom's revised taxonomy (Valamis, 2022)



The knowledge or remembering level, or Level 1, is the lowest level in the hierarchy. At this level, learners must memorise and recall basic facts by naming, recognising, identifying or labelling them (Chatterjee & Corral, 2017; Sobral, 2021; Valamis, 2022).

Understanding and comprehension are discussed at Level 2. A minimal comprehension of the material is needed at this level, with an emphasis on meaning (Chatterjee & Corral, 2017; Sobral, 2021; Valamis, 2022). Here, educators ask learners to paraphrase, rephrase, explain or give examples of information.

The application of their prior learning is covered in Level 3. Learners are encouraged to use their previously acquired understanding and competencies in novel or unusual contexts (Chatterjee & Corral, 2017; Sobral, 2021; Valamis, 2022).

Analysis is required at Level 4. Before drawing any conclusions, learners must divide content into portions and look closely at each area to discover the underlying constructs and relationships (Chatterjee & Corral, 2017; Sobral, 2021; Valamis, 2022).

Evaluation of information and content forms part of Level 5. Learners are supposed to assess, summarise, critique, or judge knowledge following a predetermined standard (Chatterjee & Corral, 2017; Sobral, 2021; Valamis, 2022).

Developing or creating original ideas is enacted at Level 6. Based on their prior knowledge, learners are required to create, construct or invent a new construct, pattern or structure (Chatterjee & Corral, 2017; Sobral, 2021; Valamis, 2022).

This taxonomy is the one I have chosen because it connects well to the critical competencies required by the 4IR, as discussed in section 2.2.1.1.

Combining SMART learning outcomes and Bloom's taxonomy

According to Chatterjee and Corral (2017), the notion of so-called SMART learning outcomes and using Bloom's taxonomy are necessary to create effective learning outcomes. Each level on Bloom's taxonomy correlates with an action verb that educators use to set outcomes. When combining these action verbs with the principles of SMART, these outcomes communicate expectations of each learner in more exact terms.

b) Assessment opportunities

Assessment is concerned with whether the learner achieved the desired outcome. According to Klint (2020) the term "assessment" refers to any tool that evaluates, measures, monitors, observes and documents learning progress, academic preparation, skill development or educational needs of learners. Howard (2007) advocates considering a wide range of types of assessment to serve as evidence of learning and achievement of the desired experiences and competencies. Aligned with different types of assessment various assessment methods are suggested by Wiggins and McTighe (2005). According to Gareis and Grant (2015) there are three fundamental roles of assessment in education, namely pre-assessment, formative and summative assessment.

Pre-assessment, also known as baseline assessment, refers to the judgement of learner learning and current level of knowledge, competencies and abilities prior to learning opportunities (Gareis & Grant, 2015). The aim of this assessment is to determine the knowledge, competencies and experiences that learners already have (Cilliers et al., 2012).

Formative assessment is known as the evaluation of learners' learning that is included in the teaching process (Gareis & Grant, 2015). This type of judgement is intended to help with instructional decisions, to give learners and educators feedback and to give learners a tool for self-evaluation (Bacquet, 2020). Klint (2020) explains that these assessments include classroom assessments, quick quizzes, observations, etcetera.

Summative assessment refers to the judgement of learner learning following a particular instructional time (Gareis & Grant, 2015). The aim of summative assessment is to determine learner understanding, to make decisions regarding the effectiveness of the curriculum (Bacquet, 2020) and to grade higher order learning beyond the level of understanding. Klint (2020) adds that summative assessment can be used for grading learners' work, decision making around learning opportunities and educator professional development (discussed below).

c) Teaching and learning experiences and opportunities

Howard (2007) believes that learning experiences are designed to enable learners to experience the desired learning results. According to Drake and Reid (2018) teaching and learning experiences include developing daily learning opportunities as well as formative assessment to reach the desired learning experiences. It is argued that educators need to develop their competencies to be able to design effective learning opportunities to ensure positive learning experiences (Shen et al., 2007). This emphasises the need for educators' professional growth and development.

2.2.6 Contributions of backward design to an effective coding and robotics curriculum

The backward design approach has multiple contributions to the development of an effective coding and robotics curriculum. It plays an essential role in shaping a meaningful educational experience for learners.

To begin with, educators establish a strong basis for the entire learning process by initiating the curriculum development process with well-defined learning objectives (Wiggins & McTighe, 2005) or learning outcomes as it is known in South African contexts. Education Reform (2013) asserts that these objectives act as the fundamental principles that determine the content, activities and assessments incorporated in the curriculum. Explicit learning goals enable educators to design a targeted and intentional curriculum with precise competencies and knowledge domains pertinent to coding and robotics (Bowen, 2017).

Moreover, the backward design approach highlights the significance of relevance. Bowen (2017), Education Reform (2013) and Wiggins and McTighe (2005) point out that by beginning with the desired outcomes, educators can customise the curriculum to meet the specific requirements of the learners and the ever-changing technological environment. This relevance guarantees that learners are not solely acquiring knowledge of coding and robotics constructs, but also developing competencies that are practical and highly valuable in real-life situations. It serves as a link between theoretical knowledge and practical application, equipping learners with the necessary competencies to navigate future educational and professional environments.

The backward design approach makes a significant contribution through alignment with educational standards (Button, 2021; McTighe, 2012). By ensuring that the coding and robotics curriculum aligns with established educational standards, educators facilitate a smooth integration of these subjects into the wider educational framework. This alignment not only satisfies regulatory mandates but also guarantees that learners acquire a comprehensive education, incorporating coding and robotics in conjunction with other academic fields.

The backward design approach enhances the efficacy of a coding and robotics curriculum by equipping educators with a systematic and intentional method to create targeted, pertinent and objective-driven educational experiences. Through the implementation of standards and the promotion of coherence, this approach guarantees that learners acquire a well-rounded education that not only imparts technical knowledge but also cultivates critical thinking, problem-solving abilities and a profound comprehension of the subject matter. By employing this approach, educators can effectively lead their learners through a meticulously organised and significant learning process in the domain of coding and robotics.

2.2.7 Introduction to action research in education

Action research in education is a dynamic and iterative process that focuses on educators actively engaging in critically analysing and enhancing their teaching practices (McNiff, 2016). Clark, et al. (2020) state that action research is grounded in the principles of introspection and cooperation, and that this approach aims to foster beneficial transformations in the educational setting. In the field of education, action research entails a constant process of planning, implementing, observing and reflecting (Du Toit, 2012). This framework creates opportunities for educators to self-empower with a view to improving their methods of facilitating and assessing learning and making valuable contributions to curriculum development.

Action research is fundamentally a process of reflection in which educators assume the dual roles of researchers and practitioners (Feldman et al., 2018). Through a systematic examination of their teaching practices, educators acquire valuable understanding of the efficacy of their techniques and pinpoint areas that require enhancement (McNiff, 2016). This reflective aspect sets action research apart from other means of professional development, making it a valuable tool for educators dedicated to cultivating a culture of transforming their classroom practice.

Another characteristic that sets action research apart from other processes is its collaborative and participatory nature. According to McNiff (2016) educators actively collaborate with colleagues, administrators and occasionally learners, cultivating a community-orientated approach to enhancing education. Gogus (2012) explains that the collaborative ethos not only expands the range of perspectives but also establishes a supportive network for exchanging ideas, experiences and best practices. By engaging in collaboration, educators can tackle challenges as a collective, explore inventive strategies and jointly contribute to the advancement of effective methods of facilitating and assessing learning.

An action research process is characterised by continuous cycles, consisting of different steps such as planning, acting, observing and reflecting (Gogus, 2012). By being cyclical, educators can continuously modify and improve their strategies through ongoing observations and reflections (Hayman et al., 2012). This statement recognises that teaching is not a fixed, but rather a dynamic and adaptable practice that necessitates ongoing transformation. The iterative nature of action research allows for real-time adjustments, fostering a flexible and adaptive learning environment.

Action research is highly applicable in the field of curriculum development in general and my study in particular. As educators analyse their methods of facilitating and assessing learning, they acquire valuable insight into the influence of learning opportunities on learner learning. The real-time feedback enables educators to customise a curriculum to more effectively address the learning requirements of a wide range of learners. By utilising observations and reflections to inform decision making, the curriculum development process can be transformed into a responsive and learner-centric approach.

Furthermore, action research offers a pragmatic approach to tackling the distinct obstacles encountered by educators (Gebhard, 2005). Action research provides a methodical and knowledgeable approach to adapting to new technologies, incorporating innovative methods of facilitating learning and addressing diverse learning needs. By incorporating action research into the process of curriculum development, educators can synchronise their teaching methodologies with the changing requirements of learners and the educational environment (Macintyre, 2012).

In summary, the application of action research in the development of a coding and robotics curriculum is highly advantageous. It not only allows educators to stay current with technological advancements but also ensures a tailored and responsive approach that meets the diverse needs of learners in this dynamic and ever-changing field. Through the continuous cycle of observation, reflection and adaptation, educators can create a curriculum that not only imparts technical knowledge but also instils problem-solving competencies, creativity and a deep understanding of the coding and robotics domain.

2.2.8 Professional development

Professional development in education has been a topic of investigation by many researchers over the years. Many researchers refer to the continual education and training that educators take to advance their subject matter expertise and teaching opportunities (Kennedy, 2016; Philipsen et al., 2019; Van, 2020). Van (2020) further explained that this process continues throughout an educator’s career, thus referring to lifelong learning. Numerous opportunities are available to professionally develop, including workshops, seminars, online courses and degree programs (Kennedy, 2016). According to Philipsen et al. (2019) professional development can help educators acquire new strategies for involving and supporting learners, stay current on the most recent research and best practices in education and improve their overall performance in the classroom. Action research in education is a tool for professional development.

2.2.8.1 Action research and professional development

Extensive research has focused on professional development in education, specifically the ongoing education and training that educators pursue to improve their knowledge in specific subjects and creation of learning opportunities (Kennedy, 2016; Philipsen et al., 2019; Van, 2020). Van (2020) broadens this construct to include the entire span of an educator's professional life, highlighting the importance of continuous learning. Diverse options exist for enhancing professional competencies, such as workshops, seminars, online courses and degree programmes (Kennedy, 2016). According to Philipsen et al. (2019), participating in professional development allows educators to gain new techniques for engaging and assisting learners, stay updated on the most recent research and apply the most effective methods in education, thereby improving overall classroom performance.

Action research is a methodical investigation into a social situation or educational practice, conducted with the explicit goal of making improvements. It is a powerful tool for enhancing professional development (Elliot as cited in Feldman et al., 2018). Van (2020) highlights the significance of action research in enhancing educators' professional practices by motivating them to carry out investigations aimed at identifying remedies to practical challenges faced in their teaching settings. This dynamic approach to professional development aligns with the construct of lifelong learning, promoting a continuous cycle of improvement throughout an educator's career.

Participating in action research as a method of professional development enables educators to actively engage in the analysis and enhancement of their teaching methods (Çelïk & Dïkïlitaç, 2015; Pickard, 2013). Pickard (2103) highlights that by conducting a methodical examination of their own classrooms, educators acquire valuable knowledge regarding the efficacy of their teaching methods, the influence on learner learning and the overall dynamics of the learning environment. White and

Cooper (2022) explain that action research functions as a contemplative instrument that enables educators to enhance and modify their methodologies by relying on evidence and immediate feedback, ultimately fostering their professional development.

Furthermore, action research cultivates a feeling of independence and influence among educators. According to Çeli̇k and Di̇ki̇litaç (2015), through active engagement in the research process, educators assume the role of catalysts for change within their own classrooms; assuming responsibility for their own professional growth and development. This practical approach not only enhances their comprehension of teaching methods but also fosters a feeling of empowerment, motivating educators to consistently pursue creative solutions to the difficulties they face in their teaching methods (Norton, 2009; Pickard, 2013).

Ultimately, incorporating action research into professional development programmes for educators proves to be a highly effective approach. It corresponds to the idea of lifelong learning, enabling educators to continuously enhance their methods of facilitating learning throughout their professional lives. Action research is a powerful tool that enables educators to actively participate in enhancing their teaching practices. It encourages a thoughtful and evidence-based approach to professional growth. This iterative process not only improves the quality of education in the classroom but also fosters a culture of ongoing improvement and innovation among educators.

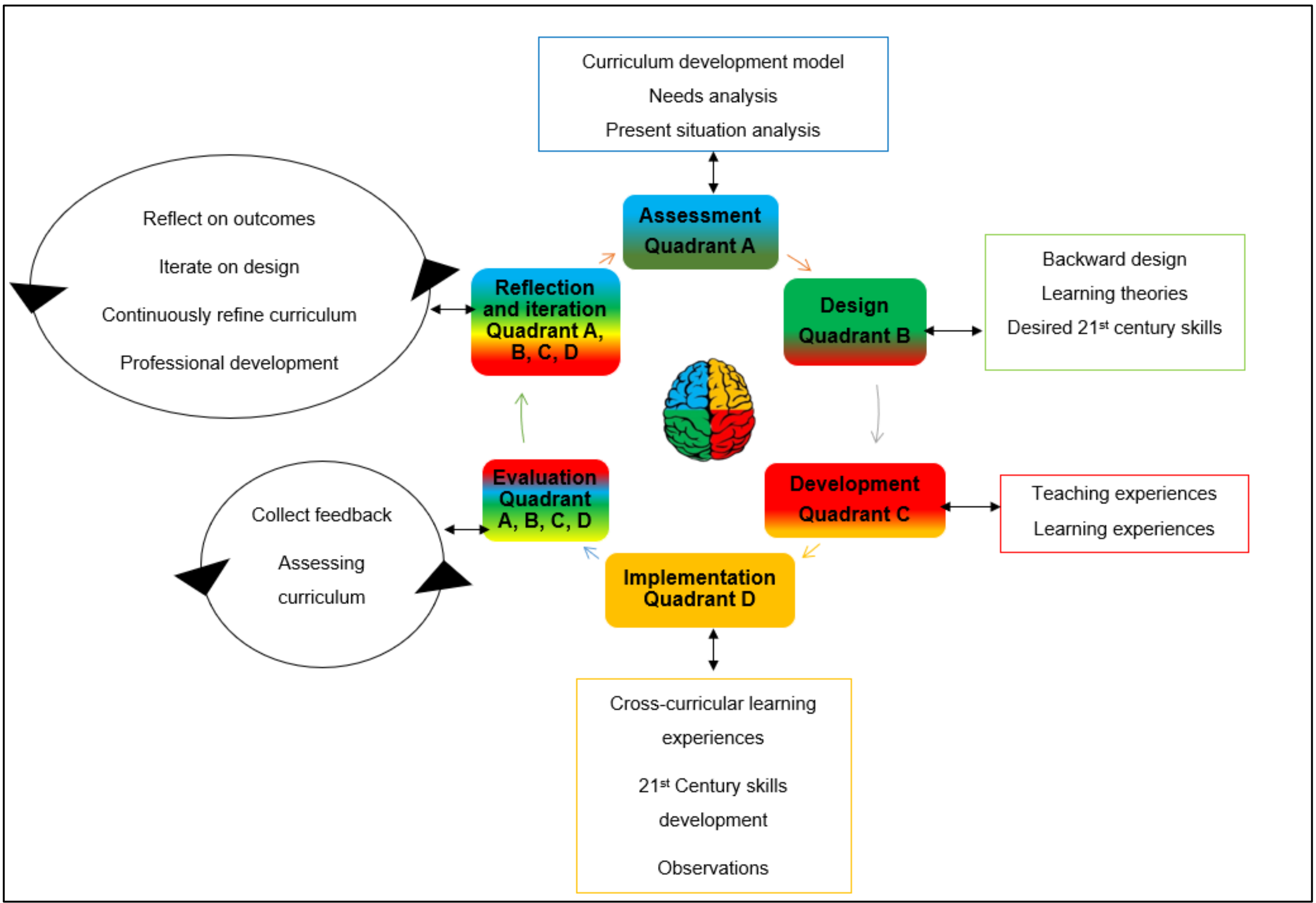
2.3 Construct frame

I have drawn up a pertinent curricular development construct frame for this study. Due to the nature of this study this framework uses a Whole Brain® Coding and Robotics Curriculum development model prototype.

The process of developing a curriculum is difficult and multi-faceted. Figure 9 illustrates how many various planning and components are involved. A curriculum development model, a needs analysis, backward design, 21st century competencies, learning theories and professional development will all be taken into account in this curriculum creation framework. All components are related to one another and complement one another, as seen in Figure 9.

Figure 9

Curriculum development construct frame



This framework suggests that in order to direct curricular development, we need a model. To support and direct my curriculum planning model, I will use Stenhouse's (1995) curriculum as a process model combined with the Whole Brain® thinking theory and action research principles. This framework not only provides a structured approach but also ensures that the curriculum caters to the diverse cognitive preferences and abilities of learners.

Assessment (quadrant A: Analytical)

Setting assessments focuses on setting clear learning objectives and outcomes for the curriculum, which is crucial for effective curriculum development. It includes selecting a curriculum development model such as the model designed by Stenhouse (1975), selecting learning theories (Leonard, 2002; Pritchard, 2017; Stenhouse, 1995), conducting a needs and situation analysis to understand the current state of coding and robotics education, and identifying gaps and areas for improvement (Li, 2014). Conducting learner assessments allows educators to tailor the curriculum to meet the specific needs and competencies of the learners, ensuring it is relevant and impactful.

Design (quadrant B: Practical)

Here the focus is on developing a curriculum structure that seamlessly integrates coding and robotics concepts. This approach should involve the backward design process, beginning with a well-defined set of desired learner competencies identified through a needs analysis (Knowledge Base, 2021). Subsequently, the learning and teaching opportunities should be designed for developing these desired competencies (Emory, 2014). Finally, the assessment opportunities should be designed which will evaluate the extent to which the desired competencies have been achieved (Education Reform, 2013).

Development (quadrant C: Relational)

Creating learning materials and resources that are accessible and engaging for both educators and learners is essential. This should be done by using the backward design as a guide, ensuring alignment with the identified learning objectives and outcomes. Establishing connections between coding, robotics and other subjects enhances cross curricular learning and reinforces learning outcomes, fostering the development of 21st century competencies such as critical thinking, communication, collaboration and creativity (Stauffer, 2019). Developing strategies to foster collaboration and teamwork among learners promotes a supportive learning environment, preparing them for future challenges in a rapidly evolving world.

Implementation (quadrant D: Experimental)

Implementation involves the execution of the intended curriculum. Implementing the curriculum in classrooms ensures that it aligns with the intended learning objectives and provides opportunities for 21st century competencies development. Encouraging learners to explore and experiment with coding and robotics concepts fosters creativity and innovation; essential competencies for success in the digital age. Collecting feedback from learners helps in assessing the effectiveness of the curriculum and making necessary adjustments to enhance their learning experience and skill development.

Evaluation (Integration of all quadrants)

Evaluating the curriculum based on its influence on learners' coding and robotics competencies is crucial. Assessing its effectiveness in promoting whole brain thinking ensures that it meets the holistic needs of learners. Using feedback and data to make improvements to the curriculum ensures its continuous enhancement and relevance.

Reflection and Iteration (Integration of all quadrants)

Reflecting on the outcomes of the curriculum implementation, including feedback from learners and educators, helps in identifying areas for improvement and professional development needs. Iterating on the curriculum design based on this feedback and reflection enhances its effectiveness and relevance to learners' needs. Continuously refining the curriculum to adapt to changing educational trends and technologies ensures its sustainability and long-term impact, requiring ongoing professional development for educators to stay abreast of these changes.

In conclusion, the Whole Brain® Curriculum Development Construct frame provides a comprehensive and holistic approach to developing an action research-driven coding and robotics curriculum. By integrating analytical, practical, relational and experimental thinking, this framework enhances learners' cognitive competencies and abilities, preparing them for future challenges in coding and robotics education.

2.3.1 Construct frame: Curriculum development and its interconnections

The curriculum development model provides the overarching structure for the entire framework, as it serves as the central focus of the interconnections. Needs analysis informs curriculum developers about the specific requirements and learning needs that should be addressed in the curriculum. Backward design helps ensure that the curriculum's learning outcomes, learning opportunities and assessment opportunities are aligned and cohesive. Integration of 21^{st} century competencies within the curriculum development process enhances the relevance and applicability of the curriculum in the modern world. Understanding learning theories guides the selection of appropriate learning opportunities, content organisation and assessment methods in the curriculum. Professional development plays a vital role in equipping curriculum developers with the knowledge and competencies necessary to effectively implement the curriculum model, integrate 21st century competencies and apply learning theories in practice.

Overall, this theoretical framework highlights the interconnectedness between curriculum development, needs analysis, backward design, 21st century competencies, learning theories and professional development. It emphasises the importance of a systematic and learner-centred approach to curriculum development while considering the dynamic nature of education and the needs of the 21st century learners.

2.4 Conclusion

In conclusion, this chapter has set the stage for a comprehensive exploration of the existing body of research on coding and robotics in the classroom. Beginning with T.S. Eliot's quote on the transformative power of literature, I have paved the way for understanding how scholarly endeavours can shape and enhance our educational landscape.

The literature review, as outlined by Christensen, et al. (2015), Leedy, et al. (2019), and Maree (2020), has been presented as a critical and systematic examination of various facets related to coding and robotics in education. This review extends beyond the conventional Chapter 2 structure, emphasising that literature is not confined to a single chapter but is an integral thread woven throughout the study.

The overview of critical bodies of knowledge, including industrial revolutions, the impact of the Fourth Industrial Revolution (4IR) on education, 21st century competencies, assessment practices, coding and robotics, curriculum development, needs analysis and educator professional development, has provided a broad context for the subsequent discussions. The construct frame introduced in this chapter is a key element, illustrating its relevance in the development of an action research-driven Whole Brain® coding and robotics curriculum.

As I navigated through the detailed subheadings, ranging from the industrial revolutions to the contributions of backward design and the introduction of action research in education, a comprehensive understanding of the complexities surrounding curriculum development and educational practices emerged. The exploration of various learning theories, curriculum development models and the scope of the curriculum further enriched my perspective.

This literature review not only serves as a precursor to the upcoming research but also emphasises the dynamic nature of knowledge creation and its application in the field of education. The subsequent section of the study promises a deeper dive into the construct of frames of mind, adding depth to the understanding of this crucial aspect. The interconnected nature of the construct frame, curriculum development and its various components underscores the complexity of the educational landscape, offering a robust foundation for the forthcoming chapters.

3. CHAPTER 3: NAVIGATING THE METHODOLOGICAL LANDSCAPE

3.1 Introduction

"The only way to do great work is to love what you do." Steve Jobs (2005)

This quote by Steve Jobs (2005) highlights the importance of passion and dedication in any project or research study. With passion and dedication, one can transform a good methodology into a great one and achieve great work. A methodology is a crucial component of success in any endeavour. The methodology is a set of principles, procedures and techniques that are employed to design, analyse and implement a particular project or research study (Creswell, 2014; De Vaus, 2001; Leavy, 2017). By explicating the methodology, I outline the action research process used.

3.2 Research philosophy

In grounding the philosophical underpinnings of this inquiry, the guiding paradigm is firmly situated within the domain of action research, as endorsed by Anand al. (2020) and Khatri (2020). Challenging traditional perspectives, my critical stance contends that action research surpasses the confines of a mere methodology, elevating itself to the status of a comprehensive philosophy with unique constructs, values and research approaches (Burns, 2005; Longstreet, 1982).

The proposition that action research constitutes a paradigm within social science research demands a comprehensive exploration of paradigms and their influential role in shaping research methodologies. Building upon the foundational work of Burns (2005) and Longstreet (1982), which underscores the ontological, epistemological and methodological underpinnings of research paradigms, this study delves into the nuanced impact of paradigms on researchers' worldviews.

Acknowledging the diversity of paradigms, as illuminated by McAteer (2013), who introduces unique ideals, constructs and methods specific to action research, I adopted a critical lens, opting for the term 'constructs' aligned with my constructivist epistemology, thereby challenging existing terminology. McAteer's (2013) delineation of action research emphasises its distinctive features, including real world problem-solving, collaborative techniques, iterative cycles of action and reflection and the generation of contextualised knowledge (Akdere, 2003). While recognising

Swepson's (2014) acknowledgment of the beneficial aspects of action research, a crucial distinction is made regarding the term 'technique,' asserting that action research is not merely a collection of techniques but an evolving and dynamic process utilising various techniques as a means to an end.

My contention regarding action research extends to the core features articulated by McAteer (2013), emphasising real world problem-solving, collaborative techniques, iterative cycles of action and reflection and the generation of contextualised knowledge (Akdere, 2003). While acknowledging the positive aspects highlighted by Swepson (2014), I introduce a crucial distinction concerning the term 'technique.' For me, action research is not a mere compilation of techniques; rather, it embodies a dynamic and evolving process utilising various techniques as integral means to achieve a broader end.

In addition to the overarching action research philosophy, this study firmly embraces an interpretivist ontology and socio-constructivist epistemology. The study or perception of reality is referred to as ontology (Mabila et al., 2017; Sefotho, 2018). The social reality and the knowledge that may be learned and developed from it are referred to as epistemology (Maree, 2016; McNiff, 2016). Further, according to Cohen, Manion, and Morrison (2007), epistemology refers to the presumptions that underlie knowledge, as well as how information is obtained and shared with others.

An interpretive ontology posits that reality is socially constructed and understood through the subjective meanings individuals attribute to their experiences (Maree, 2020). This aligns with the qualitative research tradition adopted in this study, emphasising the exploration and understanding of experiences, perspectives and occurrences.

Furthermore, a socio-constructivist epistemology underscores the belief that knowledge is actively constructed through social interactions and is context dependent (Maree, 2020). Within this epistemological framework, the study recognises that reality is shaped by social constructions, aligning with the nuanced exploration and interpretation of subjective phenomena inherent in qualitative research. Scholars such as Burr (2015) and Gergen (2015) further emphasise the social construction of reality, reinforcing the compatibility of the chosen qualitative approach with the study's epistemological orientation.

In addition to championing action research as a paradigm, my critical perspective aligns with an interpretivist ontology and socio-constructivist epistemology. An interpretive ontology asserts that reality is socially constructed and understood through subjective meanings, an essential foundation for the qualitative research tradition adopted in this study. My critical voice asserts that a socio-constructivist epistemology, emphasising knowledge construction through social interactions, is paramount. This perspective underscores the active and context dependent nature of knowledge, aligning seamlessly with the study's emphasis on the nuanced exploration and interpretation of subjective phenomena within the chosen qualitative approach. Scholars like Burr (2015) and Gergen (2015) amplify this critical perspective, reinforcing the understanding that reality is shaped by social constructions. In navigating this research terrain, my critical voice serves as a compass, challenging conventional boundaries and shaping the philosophical contours of this inquiry.

3.3 Qualitative research methodology

Qualitative research, which belongs to the descriptive subcategory of research, is more narrative in nature (Walia, 2015). This approach is typically used by researchers who want to investigate narrative ideas like perceptions, personal lived experiences or textual facts (Creswell & Poth, 2019; Maree, 2016). By examining meanings and lived experiences, qualitative research seeks to comprehend phenomena in contrast to quantitative research (Leedy et al., 2019). Qualitative research examines personal meanings and lived experiences that cannot be generalised or quantified (De Vaus, 2001). Some researchers, such as (Christensen et al., 2015; Maree, 2020) have combined the tenets of these strategies and carried out investigations using a variety of methodologies.

I used qualitative approaches to conducting research. The qualitative methodology explores one's understanding or sense of how reality is socially constructed (Christensen et al., 2015). The interpretive nature and intention to investigate the educators' and learners' lived experiences make the qualitative methodology appropriate.

I used a qualitative research methodology in the ways listed below. A variety of data sources, such as observations, the Herrmann Brain Dominance Instrument®, Photo evidence, text analysis, semi-structured interviews, field notes, self-reflections and informal discussions throughout different action research cycles are discussed in section 3.4. To get a thorough picture of coding and robotics in the classroom, I triangulated various data sources. The process used to analyse the data collected through these sources is further discussed in section 3.6.

By studying the adoption of a Whole Brain® coding and robotics curriculum, the nature of the research phenomenon led me to choose a qualitative approach. The qualitative approach is also appropriate for the constructivist epistemology and interpretive ontology that informed my thinking throughout the study.

3.4 Action research design

Action research is the chosen research design. The addition of auto-ethnography complements this research design. Among other contributing factors, such as positioning the study within a distinct context, it informs the style of writing. The preposition 'auto' suggests writing in first person style.

3.4.1 Action research

Action research and participatory action research are dynamic methodologies that aim to bring about transformation through active engagement with stakeholders. I have drawn inspiration from the construct, action research put forth by Randewijk and Du Toit (2022). I also highly admire the contributions of academics who mix action research and Whole Brain® thinking, such as Smit (2020). These constructs have been impacted by the innovative work of Du Toit (2013), who popularised new constructs like 'Whole Brain® participatory action research', 'Whole Brain® action research' and 'Whole Brain® constructivism'. I endeavoured to develop a distinctive and effective approach by incorporating these constructs into the study design.

Smit (2020) has significantly advanced the idea of action research by incorporating Whole Brain® thinking. Whole Brain® thinking, elaborated on in Chapter 2, is necessary for the resolving of authentic real-life problems or addressing real-life challenges such as researching one's teaching practice – from a non-traditional point of view. I opted for investigating and experimenting with innovative ideas, departing from an asset-based approach as is explained in Chapter 2. Smit (2020) suggests a comprehensive strategy that encourages innovation, creativity and thorough comprehension of complicated problems by merging Whole Brain® thinking and action research.

By introducing the constructs of 'Whole Brain® action research' and 'Whole Brain® participatory action research', Du Toit (2013) has advanced the idea of Whole Brain® thinking. To improve problem-solving and decision making processes, Whole Brain® action research combines the systematic and reflective elements of action research with the use of different thinking styles (Du Toit, 2017). I find the use of 'thinking styles' somewhat dated and prefer using 'modes of thinking'.

I approached my research in a unique and distinct way by incorporating the construct of 'Whole Brain® action research. The action research process followed was cyclical in nature, ensuring that data collection, analysis and reflection were carried out iteratively, allowing for continuous transformation.

3.4.2 Auto-ethnography

Murphy et al. (2021) state that auto-ethnography is a research approach that combines personal introspection (referred to as intrapersonal in the Theory of Multiple Intelligence) with ethnographic inquiry. It allows researchers to investigate and understand their own lived experiences within a broader social context (Murphy et al., 2021). This type of qualitative inquiry focuses on the analysis of subjective lived experiences as well as self-reflection and self-interpretation, going beyond the traditional, objective research methods (Murphy et al., 2021; Schensul et al., 2013). I discuss the idea of auto-ethnography as a transformational research approach in this section, highlighting its capacity to foster intrapersonal growth, and contribute to broader societal change. I discuss how using auto-ethnography offers researchers a special chance to engage in transformational practices by drawing on the work of Custer (2014).

Auto-ethnography focuses mainly on the examination of human experiences as it involves the process of self-reflection, the sharing of personal narratives and the subjective interpretations that are closely intertwined with human social and cultural contexts (Ellis et al., 2011). The focus lies on the researcher's self-reflection and thorough analysis of their own prejudices, advantages and viewpoints within the specific social and cultural context (Ellis et al., 2011). Mara and Thompson (2022) explain that it challenges scholars to consider critically their own lives, subjectivities and identities in relation to more extensive socio-cultural systems. According to Custer's (2014) auto-ethnography employs a complex blend of personal narratives, observations and analysis to delve into intricate social issues, surpassing mere description and creating a comprehensive body of knowledge. According to Ellis et al. (2011), auto-ethnography is similar to transformational research approaches because it aims to offer practical opportunities for personal growth and has the potential to bring about significant changes at both individual and societal levels. They further explain that researchers can become aware of their own biases, privileges and blind spots by reflecting on these and by actively engaging in self-introspection. This self-introspection process promotes reflexivity, allowing researchers to critically assess their own presumptions and contest prevailing paradigms (Custer, 2014).

In summary, auto-ethnography is a transformative research approach that encourages self-reflection, challenges dominating narratives, bridges personal and social contexts, fosters empathy and understanding, empowers marginalised voices, promotes methodological innovation and evokes emotional and aesthetic responses (Custer, 2014).

The foundation of my auto-ethnography is the idea that my intrapersonal lived experiences in my teaching practice are inextricably linked to the social and cultural contexts of the school in which they take place.

As a practitioner researcher, I developed an acute awareness of my own biases towards what is commonly referred to as 'best practice,' and recognised the privileges associated with teaching in a private school. Through introspection, I also identified areas where I had potential blind spots, particularly in terms of inclusivity and accessibility. This process of self-reflection and active engagement in self-introspection allowed me to critically examine my assumptions and challenge prevailing paradigms.

This self-introspection was instrumental in refining my methods of facilitating learning. I recognised the need to approach cutting edge practices with a discerning eye, understanding that what is considered 'best practice' may not always be universally applicable. Furthermore, acknowledging the privileges inherent in a private school environment prompted me to seek ways to level the playing field for all learners, regardless of their background or circumstances.

In terms of inclusivity and accessibility, I came to understand the importance of providing a learning environment that caters to diverse needs and perspectives. This realisation led me to implement inclusive teaching strategies and explore resources that would ensure every learner felt valued and supported.

The foundation of my auto-ethnographic journey rests on the understanding that my experiences as an educator are intrinsically tied to the social and cultural context of the school environment. This awareness has been pivotal in shaping my education philosophy and approach.

By actively engaging in self-reflection and introspection, I have not only honed my teaching practice but also contributed to a more inclusive and equitable educational experience for my learners. This process has solidified my belief in the transformative power of auto-ethnography within the realm of education.

Based on my advocating for transformation, I endeavoured to ensure that my teaching practice became exemplary of a cutting-edge practice.

3.5 Data collection

Any data collection procedure is essential during a research project because it establishes the groundwork for developing insightful data sets and reaching reliable results (Creswell, 2014). Denzin and Lincoln (2018) argue that the reliability and validity of study findings depend on the meticulous choice and use of suitable data collection techniques, which can be triangulated. Triangulation, in the realm of research methodology, pertains to the utilisation of diverse techniques or sources to authenticate and corroborate discoveries (Gosper & Ifenthaler, 2014; Maree, 2016, 2020). Maree (2019) explains that researchers can strengthen the reliability and trustworthiness of their findings by using various methods to collect data. This helps reduce the influence of potential biases or limitations that may be present when relying on just one method. Triangulation is the process of analysing and comparing information from various perspectives, methods or sources in order to achieve a more comprehensive and reliable understanding of the phenomenon being studied (Christensen et al., 2015).

I examined data collection methods and went over numerous approaches that could be useful to collect data. Flick (2018) is of the view that the goal of data collection is to compile pertinent and trustworthy information that responds to study objectives or research questions. He explains that researchers must carefully assess the nature of their study, the intended audience and the precise goals they hope to accomplish. Patton (2014) is of the view that researchers can obtain a complete and nuanced picture of the events under study by using a variety of data collection methods. The landscape in which this study's data collection took place is outlined and discussed next.

3.5.1 Living landscape of action

3.5.1.1 Physical environment

The classroom is equipped with ten large desks, arranged in a way that allows for collaborative group work. There are 16 learners divided into eight groups of two learners each. Each group has access to one LEGO® Spike Prime™ Robotics set, consisting of building elements, motors, sensors and a programmable brick. Additionally, each group has one tablet for coding and programming the robots. I use a projector for displaying building instructions and visuals, and a demonstration desk to showcase building techniques and coding examples.

3.5.1.2 Collaboration and teamwork

Learners work in pairs within their groups, fostering collaboration, communication and teamwork competencies. Group members collaborate to brainstorm ideas, design and build their robots and program them to perform specific tasks. Learners share responsibilities, take turns and support each other in problem-solving and troubleshooting. Learners engage in hands-on learning experiences by physically constructing robots using LEGO® building elements. They follow building instructions, experiment with different configurations and explore creative solutions to design challenges. The tangible nature of building and manipulating robots enhances spatial intelligence, fine motor competencies and kinaesthetic learning.

3.5.1.3 Coding and programming

Learners use the provided tablets to program their robots using visual block-based coding software. They learn programming constructs such as sequencing, loops, conditionals and variables to control the behaviour of their robots. Programming the robots allows learners to apply logical thinking, problem-solving strategies and computational competencies.

3.5.1.4 Facilitating learning

The coding and robotics curriculum study is based on constructivism, which emphasises active learning. The facilitation of learning in this study involves an immersive and holistic approach that engages learners using a Whole Brain® perspective. I played a pivotal role in developing and executing practical coding and robotics activities that accommodated a wide range of learning preferences. These activities were meticulously designed to promote exploration, experimentation and problem-solving.

By promoting cooperative learning environments, I fostered learners' engagement in team-based activities. I cultivated an environment conducive to knowledge sharing, idea exchange and collaborative problem-solving among learners through group projects and activities focused on coding challenges. The adoption of this cooperative method not only cultivated intercommunication abilities but also facilitated the exchange of varied viewpoints, enhancing the overall educational experience.

I facilitated project-based learning experiences for learners, enabling them to apply coding and robotics principles to real-life situations. In my role as a facilitator, I offered assistance, materials and direction to learners, while also granting them the freedom to independently investigate and generate. Project-based learning fostered a sense of ownership and creativity among learners in line with constructivist principles of active and experiential learning.

By integrating reflective practices into the curriculum, I encouraged learners to engage in critical analysis of their learning processes. By engaging in journalling, self-assessment and regular reflections, I fostered metacognition. This approach enabled learners to actively assess their comprehension, establish educational objectives and assume accountability for their educational progression, thereby cultivating intrapersonal intelligence.

Understanding the significance of involving Whole Brain® learning, I incorporated artistic components into coding and robotics endeavours. This entailed promoting innovative design thinking, integrating visual aesthetics into robot design and investigating the convergence of coding with music and storytelling. This approach sought to foster creativity and cater to different intelligences, thereby promoting a comprehensive learning experience.

I enhanced the process of learning by placing emphasis on the pragmatic utilisation of coding and robotics abilities. I facilitated the connection of learners' learning to meaningful contexts by presenting them with genuine, practical challenges. This approach was in line with the existential intelligence, encouraging learners to contemplate the wider importance and influence of their coding and robotics pursuits.

In my role as a facilitator, I provided learners with scaffolding and assistance tailored to their specific needs. By providing individualised learning opportunities, supplementary materials and specific evaluations, my goal was to establish a learning atmosphere that embraces diversity. This approach recognised the varying degrees of prior knowledge and competencies among learners, creating a nurturing environment for their growth.

My primary responsibility as the educator in the Whole Brain® coding and robotics curriculum was to establish a dynamic and inclusive learning environment. Through the integration of various pedagogical approaches, promotion of collaborative efforts and stimulation of reflective thinking, my objective was to create a learning environment in which learners actively constructed knowledge, participated in purposeful exploration and acquired a profound comprehension of coding and robotics principles.

3.5.1.5 Inquiry and exploration

Learners are encouraged to explore and experiment with their robots beyond the given challenges, fostering curiosity and independent inquiry. They can propose and solve open ended problems, test hypotheses and adapt their robots to perform new tasks or tackle real world scenarios. The classroom environment supports a culture of exploration, where learners are free to ask questions, share discoveries and learn from their peers.

3.5.1.6 Reflection and documentation

Learners engage in reflective practices by documenting their design processes, challenges faced and solutions found. They maintain engineering notebooks or digital portfolios to record their observations, reflect on their learning experiences and evaluate the effectiveness of their designs and programming codes. Reflection and documentation promote metacognition, self-assessment and the development of a growth mindset.

The living landscape of this classroom (as presented in section 3.5.1.) provides an interactive and collaborative space for learners to engage with robotics, coding and problem-solving. By combining hands-on building, coding activities and thoughtful methods of facilitating and assessing learning, this environment promotes critical thinking, creativity, collaboration and technological literacy. Learners actively participate in constructing new meaning, developing 21st century competencies, and cultivating a deep understanding of robotics and coding constructs.

3.5.2 Data gathering methods

3.5.2.1 Observations

Observations in research encompass the systematic and objective collection of data through the act of observing and recording the characteristics, behaviours or phenomena of interest (Creswell & Creswell, 2018). To get a personal understanding of how the participants behave, interact and engage with the Whole Brain® coding and robotics curriculum, observations were made. While the curriculum is being implemented, as the researcher I observed the execution of tasks and learner interactions. The behaviours of the participants, verbal and nonverbal communication, as well as any noteworthy occurrences or patterns, were noted in great detail in the notes that were kept in my journal. The observations offered insightful information regarding the implementation of the curriculum and its influence on learners' engagement during learning opportunities.

3.5.2.2 Herrmann Brain Dominance Instrument (HBDI®)

As explained in Chapter 1, the Herrmann Brain Dominance Instrument® (HBDI®) is a psychometric tool utilised for the assessment and characterisation of thinking preferences in individuals (Herrmann-Nehdi, 2010; Herrmann, 1995;

Herrmann, 1999). Based on the Whole Brain® Model, it classifies thinking patterns into four distinct modes: analytical, practical, relational and experimental. To determine my preferred modes of thought and brain dominance, data was gathered using the HBDI®. This determined my prevalent thinking preferences. The findings revealed my modes of thinking. My thinking preferences served as a baseline for my choice of interview questions, journaling, etcetera. This information also informed the design of the Whole Brain® curriculum with a view to accommodating the diverse thinking preferences of the learners.

3.5.2.3 Photo voicing and photo evidence

According to the findings of Wang and Burris (1997), photo voice is a data collection strategy that offers a pragmatic approach to visually depict the real-life experiences of individuals participating in research. Participants were given the chance to visually convey their experiences by using photo voicing and photo evidence. I took photo images of learners while partaking in the different aspects of learning opportunities, for example, their worksheets, coding, designs and robots.

3.5.2.4 Text analysis

Text analysis is the examination of written or verbal content with the aim of extracting meaningful insights (Du Toit, 2012). This method involves examining text produced during the learning process, as well as educational materials or media that support the facilitation of learning (Leedy et al., 2019). Text analyses were used to examine an array of written materials produced and used by the participants and researcher, such as the worksheets, designs made by learners, reflections made by the learners and myself and my plans for learning opportunities and projects. This analysis helped identify themes and patterns in the participants' written expressions related to the curriculum implementation. To find recurrent themes, patterns and significant constructs in the textual data, text analyses including thematic analysis and content analysis were used.

3.5.2.5 Semi-structured interviews

A semi-structured interview is a data collection method that relies on asking questions within a predetermined thematic framework (Adams, 2015; Creswell, 2014; Creswell & Poth, 2019). To understand the experiences, perspectives and attitudes of primary school learners about the Whole Brain® coding and robotics curriculum, semi-structured interviews were conducted. A series of open-ended questions served as the interview guide, allowing participants to share their ideas and offer in depth responses. For additional analysis, the interviews were audio recorded and transcribed. These interviews provided a deeper understanding of participants' perspectives, feedback and suggestions for improvement of the curriculum in general and in teaching and assessment practices in particular.

3.5.2.6 Field notes

Field notes, as a methodological practice, involve promptly and concurrently documenting data while conducting research activities (Kawulich, 2012; Leedy et al., 2019). Throughout this study, I meticulously recorded field notes during a range of research activities including observations, interviews and interactions with participants. These field notes serve as a comprehensive collection of detailed records regarding the research setting, interactions with participants, conversations and observed phenomena. They function as a fluid documentation that captures up to date observations, unforeseen revelations and contextual elements that are influential in shaping the process of curriculum development.

The significance of field notes as a valuable repository of qualitative data resides in their ability to document the intricate context and subtle elements within the research setting (Maree, 2020). These notes enhance comprehension of the various factors that impact the curriculum development process by offering a comprehensive account of the evolving events. The immediacy of generating field notes in real time guarantees that the captured data fully encompasses the spontaneity and genuineness of the research setting (Christensen et al., 2015).

Field notes serve as an essential tool in qualitative research, providing insight into the real-life experiences of participants. These notes allowed me to better understand the shared experiences of the participants, enhancing the qualitative analysis and contributing to a more thorough exploration of the complexities involved in curriculum development.

3.5.2.7 Reflective journaling

A journal serves as a repository of the researcher's thoughts and reflections pertaining to the research process (Hayman et al., 2012). I kept a reflective journal in the form of a personal electronic diary. In this diary, I recorded my ideas, reflections and experiences as the curriculum was being implemented. I also recorded the reflections on my intrapersonal growth, challenges and discoveries using this qualitative data gathering method, which yields insightful subjective assessments of the curriculum development process and the effectiveness of the curriculum.

3.5.2.8 Informal discussions and demonstrations

Informal discussions and demonstrations are data collection techniques that entail engaging with participants and observing their behaviour within a natural or simulated environment (Creswell & Poth, 2019; Flick, 2018). I engaged parents in informal discussions and demonstrations to gather their insights, suggestions and feedback on the newly designed curriculum. This engagement aimed at involving parents as active contributors and partners in their children's education.

3.6 Data analysis and interpretation

To find patterns, themes and meanings, non-numerical data must be examined and made sense of. This process is known as qualitative data analysis and interpretation. Qualitative research is used to investigate complex phenomena, such as beliefs, attitudes, experiences and social interactions that cannot be quantified (Leavy, 2017; Mohajan, 2018; Neuman, 2014; Walia, 2015). Understanding the background of the study problem and creating a comprehensive, in depth description of the data depend on qualitative data analysis (Durdella, 2019; Groenland & Dana, 2020).

The analysis and interpretation of qualitative data entails distinct stages. According to Leavy (2017), Leedy et al. (2019), and Nowell et al. (2017), it begins with the systematic documentation, recording and transcription of the data. This lays the foundation for subsequent organising and structuring, typically by topic or theme (Leavy, 2017; Leedy et al., 2019; Nowell et al., 2017). I employed semi-structured interviews, along with detailed field notes and observations, to collect the raw data, which was subsequently transcribed. This meticulous process forms the bedrock for comprehensive analysis and interpretation in qualitative research.

Data labelling, also known as data coding was next (Maree, 2020). Data coding is the process of giving the data labels or tags with the aim of finding patterns, topics and classifications in the data (Leedy et al., 2019; Maree, 2020). These authors state that the coding of data can be carried out manually or with the aid of computer programs. They further explain that as the study advances, codes may be added or updated seeing that the coding is an iterative process. I made use of Atlas.ti 23 to assist with the data analysis. The program assists researchers in organising and analysing substantial amounts of unstructured data, including transcripts of interviews, survey responses, field notes and other kinds of qualitative data (Atlas.ti 23, 2017). Atlas.ti 23 was used to code the collected data. The observations were imported into Atlas.ti 23 as notes. Audio recordings of interviews were transcribed and then imported into the Atlas.ti 23 software from an external device. Codes, functioning as markers, classified observed behaviours, interactions and involvement were used. In a classroom setting, codes such as "learner participation" and "educator instructions" were used to denote particular elements of observations. The data was categorised by assigning pertinent codes to specific segments, linking the data to corresponding behaviours or interactions. For example, if a documented observation involved an instructor providing guidance to a team assigned to carry out an educational activity, labels such as "educator instructions" and "group activities" were assigned.

I also used Atlas.ti 23 to code images. I, firstly, had to import images created by participants into Atlas.ti 23. This involved transferring the visual data from the source, such as digital image files, into the software. Subsequently, the images were aligned with the corresponding text data, which typically included interview transcripts or reflective journal entries. This linking process allowed for a comprehensive understanding of the visual content in its context. For example, a photo of a coding project could be aligned with a text entry that included a description of the code's functionality and purpose. Codes were generated to capture specific themes or patterns within the visual data. These codes were designed to categorise different aspects of the learner projects, such as code quality, design elements or stages of project progress. For a design focused project, codes like "aesthetic appeal" and "usability" were created to represent these thematic elements. Additionally, an extensive evaluation framework was employed to assess and analyse the images.

This framework encompassed criteria such as technical complexity, functional demonstration, innovation and creativity, coding proficiency and aesthetics. Each criterion was assessed on a scale from 1 to 5, with corresponding weights assigned to indicate their relative importance in the overall assessment.

Text such as plans for learning opportunities, learning material, or participant generated texts and images were analysed by using Atlas.ti 23. This involved importing textual data into Atlas.ti 23. These texts were uploaded into the software for systematic analysis. Codes were generated to represent important ideas, themes or classifications within the respective texts. These codes served as labels or tags that categorised and captured the essential content of the documents. In an analysis of plans for learning opportunities, codes included "active learning strategies," "assessment techniques," or "engagement methods" to highlight key instructional elements. I then applied the generated codes to specific segments of the text data. This process involved selecting portions of the text that align with the identified key constructs and associating the constructs with the relevant codes. For example, in a learning opportunity plan, if there is a section outlining group tasks to be executed, the code "collaborative learning" was applied to this specific segment.

Analysis of semi-structured interviews were also done by using Atlas.ti 23. Initially, interview transcripts were imported into Atlas.ti 23, providing a digital repository for systematic examination. Codes were then generated to encapsulate the principal themes, subjects or ideas elicited from the interviews. These codes function as labels that categorise and encapsulate the central content of the transcripts. For instance, in an analysis of teaching practices, codes encompass "learner engagement," "assessment strategies," or "pedagogical approaches" to spotlight key educational elements. Throughout the process, I maintained memos, which served as a space to record personal reflections, interpretations and newfound understandings derived from the interviews.

Thereafter trends and themes in the data were identified. Patterns are words, phrases or constructs that recur frequently in the data (Rivas, 2018). According to Rivas (2018), themes are overarching constructs or ideas that emerge from the data. Also, according to Maree (2020), themes can be discovered by looking at data patterns or by using a theoretical framework to guide the inquiry. Themes were categorised using scholarly pointers, such as my construct frame.

After the themes were identified, the analysis of the data took place. The process of making meaning of the data and drawing inferences from it is known as interpretation (Leedy et al., 2019; Maree, 2016, 2020; Rivas, 2018). These researchers clarify that interpretation may entail developing brand new theories or constructions or it may entail contrasting the data with pre-existing theories or constructs. The interpretation must be presented succinctly and clearly, and it must be backed up by evidence drawn from the data. From a constructivist epistemology point of view, it is about constructing new meaning. Therefore, I rather use the term 'construct' – indeed, building or constructing new theories. In action research it is common to refer to practice theory (Slabbert et al, 2009), or lived theory (McNiff & Whitehead, 2001). Once the data sets had been coded, I used Atlas.ti 23 to retrieve specific coded segments. This allowed for focused analysis of particular themes, behaviours or interactions. For instance, I used the software to gather all instances coded under "learner participation" to analyse patterns on how learners engaged in executing tasks in the classroom.

Qualitative data analysis does have some drawbacks. Many researchers state that the analysis and interpretation of qualitative data demand a high level of knowledge and proficiency of interviewing participants (Leedy et al., 2019; Maree, 2016, 2020; Rivas, 2018). They further explain that the data collection methods such as interviews, observations and document analysis, utilised in qualitative research must be understood by researchers to effectively collect, analyse and interpret qualitative data. Additionally, they must be able to recognise patterns in the data to analyse and extract meaningful themes effectively from the data (Leedy et al., 2019; Maree, 2016, 2020; Rivas, 2018). During the brainstorming process, researchers must be able to recognise their biases and preconceptions and reflect on them. Researchers bring their own perspectives, assumptions and values to research which can influence data interpretation and analysis.

Analysing qualitative data provides benefits as well. According to researchers like Maree (2020), Rivas (2018), and Nowell et al. (2017), qualitative data interpretation and analysis are essential for understanding complex events and producing an extensive, in depth description of the data. They claim that the process includes data organisation, coding, pattern and theme discovery and interpretation. The assertion made by Maree (2020), Rivas (2018), and Nowell et al. (2017) regarding the importance of advanced proficiency in qualitative data analysis and interpretation requires careful examination. Developing expertise in qualitative analysis is an evolving aspect of professional development that improves and becomes more precise through continuous involvement in research activities (Yadav, 2022). Therefore, although having a high level of expertise certainly enhances the quality of analysis, it is not absolutely necessary (Yadav, 2022). Maree (2020) noted that through dedicated perseverance, guidance from mentors and a steadfast dedication to continuous learning, individuals at different points in their academic or professional journey can make significant contributions to the field of qualitative research. This viewpoint emphasises the all-encompassing character of qualitative research, enabling researchers with varying levels of proficiency and preferences for specific modes of thinking, to make valuable contributions (Leedy et al., 2019; Maree, 2020).

3.7 Quality criteria

The quality criteria of qualitative research are essential to ensure that the research is rigorous, credible and trustworthy (Cypress, 2017; Morse et al., 2002; Steinke, 2004; Sumrin & Gupta, 2021). There are several quality criteria that researchers use to evaluate the quality of qualitative research, including trustworthiness, credibility, transferability, dependability and confirmability.

3.7.1 Trustworthiness

Nowell et al. (2017) contend that the degree to which participants and researchers can have trust in the results of a study is referred to as its trustworthiness. To ensure trustworthiness, I employed triangulation, a qualitative research technique that enhances accuracy by correlating data from diverse sources or employing multiple data collection methods (Custer, 2014). Several data gathering methods were used, such as document analysis, reflective journaling, field notes, semi-structured interviews, text analysis, photo voicing and photo evidence, determining one's preferences for specific modes of thinking (using the HBDI® as a research instrument to determine my thinking preferences), classroom observations and unstructured conversations with parents. To strengthen the reliability of the findings, triangulation helped to corroborate findings.

3.7.2 Credibility

Credibility refers to the degree of accuracy of the research findings (Sumrin & Gupta, 2021). Credibility is a crucial quality feature in qualitative research since it influences how sure one can be about the conclusions of a study (Pietilä et al., 2020). To establish credibility, the research design incorporated the following measures:

3.7.2.1 Prolonged engagement

I spent significant time in the research setting, engaging with educators, learners and parents to develop a deep understanding of the context and participants' experiences.

3.7.2.2 Thick *description*

Data analysis included providing detailed descriptions of the research process, data collection methods and the context of the study. Thick description enables readers to assess the transferability of the findings to similar contexts.

3.7.2.3 Reflexivity

I maintained a reflexive journal, reflecting on their own biases, assumptions and preconceptions throughout the research process. This self-awareness ensures transparency and minimises potential bias.

3.7.3 Transferability

Transferability refers to the extent to which the findings can be applied to other contexts or settings (Pietilä et al., 2020; Leedy et al., 2019). Transferability is a crucial quality factor in qualitative research, as it defines the relevance and applicability of the research findings (Maree, 2020; Sumrin & Gupta, 2021). They go on to say that by thoroughly describing the research context, participants and data collection methods, researchers can improve transferability. To enhance transferability, the research design included a detailed contextual description. The study provided a comprehensive description of the research context, participants and the curriculum development process. This information will allow other researchers to assess the applicability of the findings to other educational settings.

3.7.4 Dependability

Dependability is the term for the continuity and long -term stability of research findings (Christensen et al., 2015). Continuity is a crucial quality criterion in qualitative research since it affects the accuracy and consistency of the research findings, according to Nowell et al. (2017). To establish dependability, I included a clear research design. The research design was thoroughly documented and transparently presented to ensure the repeatability of the study by other researchers.

3.7.5 Confirmability

Confirmability refers to the objectivity of the research findings and the extent to which they are influenced by the researchers' biases (Maree, 2020). According to Leedy et al. (2019), researchers can increase confirmability by employing a methodical and open data analysis procedure and note how their own biases and presumptions affected the research procedure and outcomes. To ensure confirmability in this study and employed reflexivity, I maintained a reflexive journal to document participants' reflections and decision-making processes. This transparency helped in reducing personal bias and enhancing objectivity.

3.8 Ethical considerations

According to Maree (2016) qualitative research seeks to gain insights into experiences, behaviours, and attitudes through the collection and analysis of non-numerical data. Pink (2020) argues that the research often involves the collection of data from human subjects, which raises important ethical considerations. I adhered strictly to the ethical standards that the University of Pretoria had approved for this project. I applied to the University of Pretoria for ethical approval of this project. I also requested permission from the school principal (since it is a private school) to begin my research (ethical clearance) after using learners from a private school. Furthermore, I adhered to the ethical considerations of qualitative research, namely, informed consent from parents and guardians, informed assent and voluntary participation of learners, confidentiality and anonymity.

3.8.1 Informed consent

Informed consent is the first ethical factor to be considered in qualitative research. Participants are told about the study's goal, their rights as participants and the risks and advantages of participating through the process of informed consent (Christensen et al., 2015; Maree, 2020). Participants' parents or guardians must provide their informed consent voluntarily and be fully aware of the goal of the study, according to Maree (2020) and Christensen et al. (2015). Additionally, they assert that researchers must let participants' parents or guardians know they can leave the study at any moment and without consequence. Participants' parents or guardians received written documents that included thorough explanations of the methods and processes used. This documentation also described how participant data would be used by the researcher in the study setting. I gave the participants' parents or guardians information on how learners participated in action research ethically. This information session was primarily concerned with safeguarding people's privacy and security while conducting research.

3.8.2 Informed assent

Informed consent is the first ethical factor to be considered in qualitative research. Participants are told about the study's goal, their rights as participants and the risks and advantages of participating through the process of informed consent (Christensen et al., 2015; Maree, 2020). Participants' parents or guardians need to provide their informed assent voluntarily and be fully aware of the goal of the study, according to Maree (2020) and Christensen et al. (2015). Additionally, these authors assert that researchers must let participants' parents or guardians know they can leave the study at any moment and without consequence. Participants' parents or guardians received written documents that included thorough explanations of the methods and processes used. This documentation also described how participant data would be used by the researcher in the study's setting. I gave the participants' parents or guardians information on how learners will participate ethically in the action research. This information session was primarily concerned with safeguarding people's privacy and security while conducting research.

3.8.3 Voluntary participation

Individuals have the freedom to decide whether they would like to join in a research project or not, which is known as voluntary participation (Arifin, 2018; Christensen et al., 2015). Arifin (2018) and Pietilä et al. (2020) are of the opinion that to prevent subjects from being forced into research projects, voluntary involvement is crucial.

They further explain that without fear of punishment or coercion, participants have the right to decide whether to take part in research projects. To help participants make an informed decision regarding participation, researchers should give them clear and straightforward information about the research project, including its goal, procedures, potential dangers and advantages (Arifin, 2018; Pietilä et al., 2020). The participants voluntarily participated. I emphasised free will when describing the study's objectives to the participants. This ensured that the participants were not under any duress to take part in the study. I prioritised the emotional security of the participants. I also gave the participants the option to voluntarily stop participating in the study and promised that any data already gathered, would be destroyed.

3.8.4 Confidentiality and anonymity

Confidentiality is another ethical issue to be addressed in qualitative research. Researchers must make sure that participant identities are protected and that personal information is kept private and anonymous (Arifin, 2018; Pietilä et al., 2020). Arifin (2018) and Pietilä et al. (2020) explain that researchers should only disclose identifiable information to people who are directly involved in the study and should only use pseudonyms when publishing their findings. I complied with all POPIA standards, or the Protection of Personal Information Act of 2013, in order to maintain confidentiality and anonymity.

3.9 Conclusion

The research endeavour involved a thorough exploration of the methodology, covering various aspects such as research philosophy, qualitative research methodology and the complexities of the action research design. The thorough documentation of data collection methods, analysis procedures, quality criteria and ethical considerations has established a strong foundation for a rigorous and methodical investigation. Throughout the research process, it became increasingly clear that passion and dedication, as emphasised by Steve Jobs (2005), are crucial in transforming the methodology from a simple set of procedures into a powerful and dynamic tool for inquiry.

The research philosophy, discussed in section 3.2, established the fundamental framework that influenced the researcher's approach and perspective. Additionally, the qualitative research methodology, outlined in section 3.3, defined the principles that directed the investigation of complex and contextually embedded phenomena. The central focus of this chapter is the action research design (section 3.4), which is a dynamic approach that combines action, reflection and collaboration in the research process. Auto-ethnography, as a methodological approach, offers a reflective perspective to the research process, enhancing the comprehension of the real-life experiences within the study.

The complex interplay of the dynamic ecosystem of action (section 3.5.1) emerged through multiple aspects, such as the physical surroundings, cooperation, coding and programming, enabling learning, investigation and discovery, and introspection and record keeping. Each of these dimensions contributed to a comprehensive understanding of the intricate nature of the action research context.

The data collection methods (section 3.5.2) were carefully selected to accurately capture the essence of the research phenomenon. These methods included a range of tools such as observations, the Herrmann Brain Dominance Instrument (HBDI®), photo voicing, text analysis, semi-structured interviews, field notes, reflective journaling, document analysis and informal discussions and demonstrations. These methods guaranteed a thorough examination of the intricate and ever-changing context being studied.

The following sections, which include data analysis and interpretation (section 3.6), quality criteria (section 3.7), and ethical considerations (section 3.8), emphasise the dedication to thoroughness, clarity and ethical principles throughout the research process. The establishment of criteria such as trustworthiness, credibility, transferability, dependability and confirmability serve as a strong basis for ensuring the methodological integrity and validity of the research findings.

To summarise, this chapter functions as both a methodological guide and a demonstration of the researcher's commitment and enthusiasm for comprehending and influencing the complexities of the research context. The integration of various methodologies and ethical considerations creates a methodological framework that is not just a procedural tool, but also a means for transformative investigation, in line with the core principles of excellence as envisioned by Steve Jobs.

4. CHAPTER 4: EMBARKING ON THE PRELIMINARY ODYSSEY

4.1 Introduction

"Begin with the end in mind." Stephen Covey (1989)

This chapter thoroughly examines the details of the research design and the results obtained from the first two phases of the action research process. Stephen Covey's (1989) guiding principle emphasises the importance of foresight in planning, which aligns well with the detailed needs analysis (phase 1) and the backward design phase 2) of this research project. The preliminary phase is focused on conceptualising the context and defining the specification of the study (Plomp, 2009) by discussing the needs analysis and backward design.

The discourse in this section revolves around the research design and results of the initial phases of the curriculum development process. Within this discourse, the chapter delves into the intricacies of specific research questions, dissecting the key elements of the needs analysis and illuminating how they converge with the overarching goals of the secondary research questions. As I navigate through this chapter, a deeper understanding unfolds, offering insights into the foundations laid and the strategic groundwork accomplished to pave the way for subsequent cycles of the research journey.

4.2 Action research phases

Based on the explanation given in Chapter 1 (section 1.3), my curriculum development involved the following tasks: I completed the HBDI®, as described in section 5.2.2 and I conducted a needs analysis to determine the profile of the school and its learners, as outlined in section 4.3. Next, I developed a basic curriculum using the principles of backward design, explained in section 4.4. Finally, I carried out a series of fourteen action research cycles, which are discussed in section 5.3.

4.3 Phase 1: Needs analysis

4.3.1 School needs

The initiation of a coding and robotics curriculum at the English medium independent school in Pretoria, South Africa, stemmed from a perceived necessity expressed by the school. This imperative arose from the overarching objective to provide comprehensive academic, sports and cultural programmes. The curriculum development targeted the explicit needs of the school, acknowledging coding and robotics as a central academic focus. In 2023, the school introduced coding and robotics as a stand-alone subject, offering weekly learning opportunities during normal teaching hours.

Upon evaluating the Department of Basic Education's proposed coding and robotic curriculum (2021a), the school recognised a misalignment with the learners' existing competencies. This realisation prompted the initiation of an autonomous curriculum development process, meticulously tailored to both the current capabilities and the envisioned skill development of the learners.

4.3.2 Learner profile

In the context of the research, it is noteworthy that invitations were extended to all learners in grade 4, encompassing a total of potential participants (how many)? aged 10 to 11 years old. However, it is essential to acknowledge that despite these invitations, some parents or learners chose to decline participation in the research study. This aspect is crucial to understanding the composition and dynamics of the participant group, as the decision to decline participation introduces a potential element of self-selection bias. The reasons for declining participation may vary and could include parental consent concerns, scheduling conflicts or individual preferences. This information is vital in providing transparency about the participant selection process and acknowledging the potential impact of non-participation on the generalisability of the study's findings. The learners in question exhibit a range of cultural backgrounds, including individuals of Afrikaans, English, Korean and Chinese descent. In order to streamline the process of conducting interviews and observations, the participants were systematically divided into groups, with each group consisting of four learners in Term 1. These were the main groups in which participants participated. In Term 2, additional LEGO® Spike Prime™ sets were obtained, leading to a change in the group arrangement, where each group now consists of only two learners.

4.3.3 Situation analysis

Photo evidence 1 offers a visual representation of a vacant classroom, characterised by elements essential for an optimal learning environment. The room features durable wooden desks paired with black plastic chairs, systematically arranged in rows and oriented towards a centrally positioned whiteboard. The educational ambiance is enriched by informative posters strategically displayed on the beige brick walls, and effective airflow is facilitated by a ceiling fan. The tiled floor contributes to the overall spatial arrangement, and though not explicitly visible in the image, the room benefits from natural illumination through windows. Despite the absence of individuals in the photograph, it effectively conveys the pedagogical functionality of the classroom. Moreover, the classroom features two chalkboards, each serving distinct purposes. One chalkboard functions as a dynamic platform for displaying weekly motivational quotes, contributing to an inspiring atmosphere within the learning space. These motivational quotes, refreshed on a weekly basis, aim to instil positivity and motivation among the learners. An illustrative example of such a quote is "The best way to predict the future is to invent it" by Alan Kay (AZ Quotes, 2024). Concurrently, the second chalkboard serves as a practical tool for communicating essential dates, such as reminders for learners to bring necessary materials from home. This dual utilisation of chalkboards enhances the communicative and motivational aspects of the classroom environment, fostering an enriching educational atmosphere.

Photo evidence 1

Actual classroom

In tandem with Photo evidence 1, Image 5 serves as an illustrative counterpart, depicting the robotics classroom. Described in the aforementioned textual context, this learning space is characterised by dual desks tailored to accommodate four to six chairs per table. Augmenting the conducive learning environment are additions such as a whiteboard and a data projector. Initially, the robotics resources were confined to six LEGO® Spike Prime™ sets. However, in subsequent terms, an expansion occurred with the acquisition of five additional sets, thereby enriching the available assets for the learners. This visual and textual documentation collectively furnishes a comprehensive portrayal of the physical layout and educational resources within the robotics classroom, further elucidating the research context and substantiating the subsequent analytical discussions.

The incorporation of a schematic representation detailing the classroom layout, including the storeroom omitted in the photograph, serves as an instrumental visual adjunct in augmenting the transparency and comprehensiveness of the research methodology. This visual rendering, delineating the entire spatial configuration, facilitates a more nuanced understanding of the spatial organisation, relative proximities, and overall physical milieu within which the research is conducted.

Image 5

Classroom layout with visible storeroom

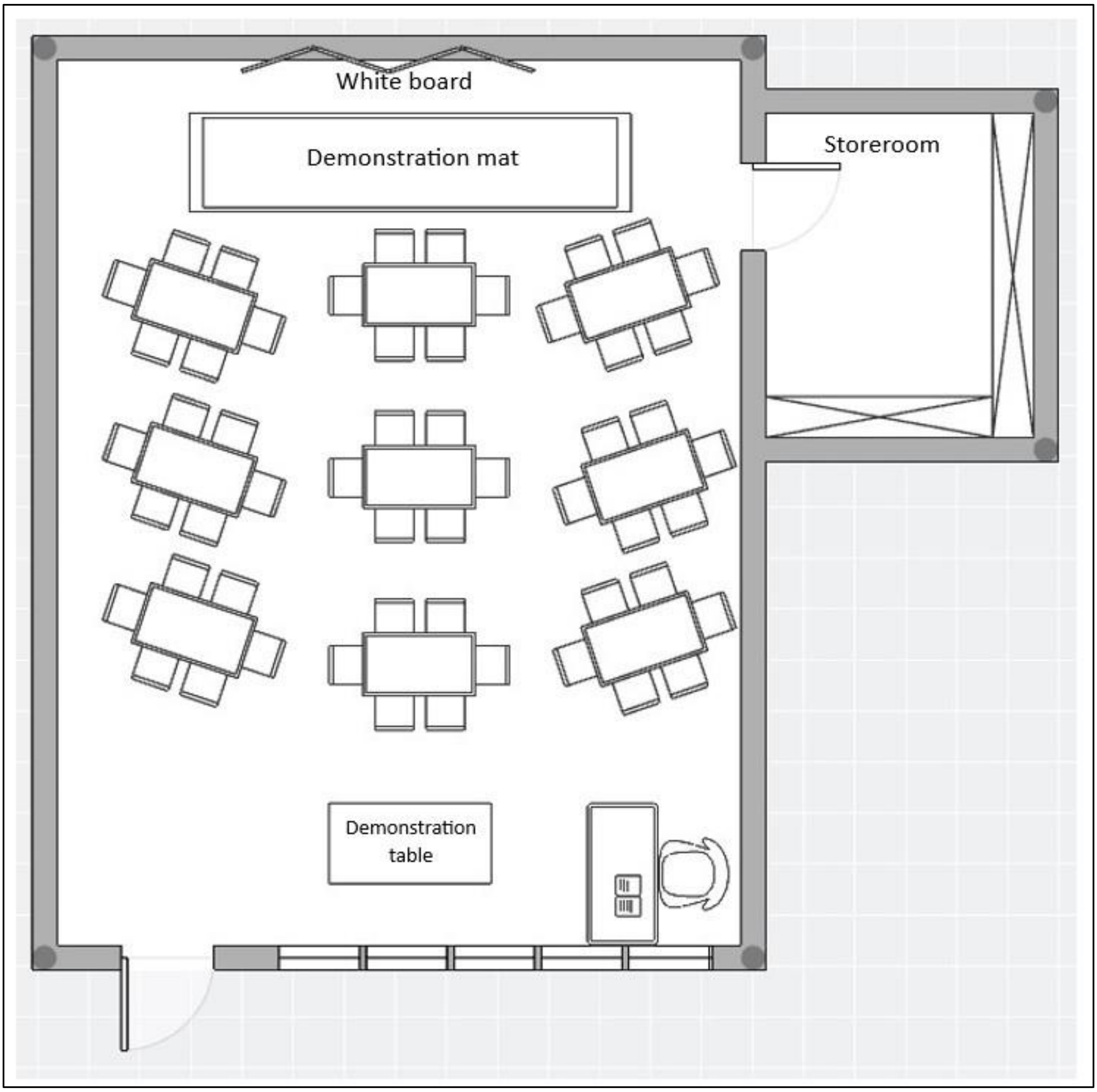


Photo evidence 2 provides a comprehensive view of a meticulously organised storage area, featuring an array of yellow bins neatly arranged on shelves to house LEGO® Spike Prime™ robotic sets. Beyond these collections, the storage space accommodates various miscellaneous items, including tablets, a designated tin for lost pieces and the essential hubs, all systematically stored beneath the shelves. This storage room, designed for both robotic sets and tablets, serves dual purposes as a repository and a practical charging station, as exemplified in the captured image.

Photo evidence 2

Sets and charging station in storage room

In correlation with the observed organisation, every individual set and tablet is conspicuously marked with a distinct number, contributing to a systematic method aimed at enhancing organisational efficiency. The numerical tagging system assumes a pivotal role in the allocation of groups, ensuring that each group is assigned a specific tablet and set in accordance with their designated numerical identifier.

Furthermore, the storage infrastructure demonstrates a thoughtful approach to efficiency, featuring a single robust extension cord integrated with two multi plug receptacles. This configuration provides an effective solution for overnight charging of devices. Importantly, each tablet and headset within the inventory is equipped with its own exclusive charger, ensuring seamless compatibility and insertion into the previously mentioned multiplugs.

This detailed organisation, systematic numbering and efficient charging solutions are reflective of my Whole Brain® Thinking Profile, characterised by quadrant B thinking style (as illustrated and discussed in section 5.2.2). This quadrant emphasises logical and structured thinking, aligning cohesively with the meticulous organisation observed in the storage room. The emphasis on clarity, systematic methods and efficient charging solutions contributes not only to the physical orderliness of the storage space but also to the overall functionality of the robotics curriculum within the research context.

Initially, tablets were not included as a component of the educational materials utilised in the study. However, during Term 1, a total of 11 Samsung Galaxy Tab A7 Lite tablets were introduced. The Samsung Galaxy Tab A7 Lite is characterised by its compact 8.7 inch display, making it a suitable choice for users prioritising portability while maintaining a satisfactory visual experience (Samsung, 2021). The tablet is designed for efficient and responsive performance, ensuring smooth multitasking and multimedia consumption owing to the Helio P22T processor (Samsung, 2021). With 3 GB of RAM, the device ensures optimal operational fluidity, complemented by a 32 GB internal storage capacity, providing sufficient space for the LEGO® Spike Prime™ application and user data (Samsung, 2021). The tablet is equipped with an 8-megapixel rear camera and a 2 megapixel front facing camera (Samsung, 2021). Operating on the Android 11 based One UI Core 3.1, the device offers an intuitive and user-friendly interface. The 5,100 mAh battery, combined with its efficient processor, contributes to extended usage periods. Photo evidence 3 depicts the box in which the tablets were originally packaged. To enhance their durability, the devices were meticulously protected using screen protectors and flip covers.

Photo evidence 3

Tablets used

In order to guarantee the protection and integrity of the resources, they were securely stored within a storeroom equipped with a lock mechanism as explained in section 4.3.1.

4.4 Phase 2: Backward design

This section demonstrates the implementation of the backward design framework by presenting Table 1. This table functioned as a visual aid to clarify the complex interaction and coordination between important components, specifically competencies, assessments and learning opportunities. The purpose of this table is to visually represent the intentional and strategic alignment that is inherent in the backward design approach. This methodological framework emphasises the organised and deliberate coordination of learning outcomes, assessment opportunities and methods of facilitating learning, with a strong emphasis on promoting consistency and meaningful learning experiences throughout the educational process. The use of a tabular format facilitated a thorough analysis of the deliberate links established between desired competencies, the evaluative mechanisms utilised and the methods of facilitating learning. This will enhance the clarity and comprehension of the pedagogical structure.

Table 1

Competency based learning and assessment framework for LEGO® robotics education

Learning opportunity 1: Building Basic Structures with LEGO® Blocks and Understanding Basic Mechanics	
Competencies	1. Operating the hub (switching on and off). 2. Activating a motor. 3. Employing the force sensor to regulate a motor. 4. Utilising the colour sensor for colour identification. 5. Applying the distance sensor to control the hub.

Assessment opportunities	**Goal:** Assess learners' proficiency in meeting specific learning outcomes and competencies related to building with LEGO® blocks and basic mechanics.
	Assessment tool: Utilise a combination of observation and specific assessment tools for gauging learners' performance.
	Type of Assessment: Formative and summative assessments to track ongoing progress and overall achievement.
Learning opportunities	**Facilitating Learning:** Employ a blend of discovery learning and self-regulated learning. Create an interactive learning environment where learners observe component functionalities.
	Teaching Experience: Facilitate an interactive learning environment where learners observe component functionalities. Encourage critical thinking to conceptualise real-life applications.
	Learning Experience: Provide opportunities for hands-on learning, encouraging the application of knowledge.

Learning opportunity 2: Problem Definition and Utilising the Colour Sensor for Story Creation	
Competencies	1. Defining a problem. 2. Utilising the colour sensor to react to three colours. 3. Creating a story with sounds and the colour sensor.
Assessment opportunities	**Goal:** Evaluate learners' competence in defining problems and utilising the colour sensor to create stories.
	Assessment tool: Use observation, participative discussion and assessment of created stories.
	Type of Assessment: Formative assessment through ongoing observation and discussion, and summative assessment of created stories.
Learning opportunities	**Facilitating Learning:** Employ constructivism, encouraging active engagement in discussions, problem-solving, and story creation.
	Teaching Experience: Facilitate hands-on tasks related to problem-solving processes. Guide technical facilitation for coding in problem-solving. Foster reflective and collaborative discussions on problem scenarios.
	Learning Experience: Emphasise experiential learning through hands-on experiences. Encourage collaborative learning through group activities.

Learning opportunity 3: Understanding Prototypes and Their Significance	
Competencies	1. Describing the purpose and significance of prototypes. 2. Recognising the benefits of utilising prototypes. 3. Generating multiple prototypes. 4. Selecting and justifying the choice of the best prototype.
Assessment opportunities	**Goal:** Evaluate learners' understanding and application of prototypes.
	Assessment tool: Use observation, note taking and group reports.
	Type of Assessment: Formative assessment during build and modification phases, and summative assessment through group reports and justification.
Learning opportunities	**Facilitating Learning:** Facilitate group work for collaborative learning. Emphasise experiential learning through hands-on experiences.
	Teaching Experience: Initiate discussions on prototypes and effective brainstorming techniques.
	Learning Experience: Foster an environment of experiential learning in building, modifying and testing prototypes. Promote collaborative learning through group activities.

Learning opportunity 4 and 5: Assessing and Comparing the Efficiency of Different Grabber Designs	
Competencies	1. Assessing and comparing the efficiency of different grabber designs. 2. Observing and analysing test results in terms of size and weight. 3. Describing the criteria for determining the best product. 4. Making recommendations based on observations. 5. Creating a product review.
Assessment opportunities	**Goal:** Evaluate learners' ability to assess and compare the efficiency of different grabber designs and make informed decisions based on observations.
	Assessment tool: Use a combination of learners' observations, test results and their product review to assess their understanding and decision-making competencies.
	Type of Assessment: Formative assessment during group work and test activities, and summative assessment through the product review and recommendations.
Learning opportunities	**Facilitating Learning:** Organise learners into pairs, fostering collaborative learning and teamwork. Facilitate the learning process by providing guidance and support, especially during the discussion and observation phases.

	Teaching Experience: Engage learners in a hands-on activity testing the efficiency of different grabber designs. Initiate a discussion on evaluation criteria and product reviews, fostering critical thinking.
	Learning Experience: Provide learners with practical experience by testing and observing grabber designs. Engage learners in reflective discussions about criteria for determining the best product. Foster creativity in making recommendations and creating a product review.
Learning opportunity 6: Defining and Customising a New Object	
Competencies	1. Defining and customising a new object. 2. Communicating the purpose and use of the "new thing." 3. Understanding the principles of design. 4. Grasping the constructs of argument and proof.
Assessment opportunities	**Goal:** Evaluate learners' ability to define, customise and communicate the use of the "new thing" while understanding principles of design, argument and proof.
	Assessment tool: Utilise definitions, customisations and effective communication of the purpose, along with comprehension of argument and proof through discussions and presentations.

	Type of Assessment: Formative assessment during pair work and experiential learning, and summative assessment through discussions, presentations and overall comprehension.
Learning opportunities	**Facilitating Learning:** Facilitate collaborative learning through pair work, promoting teamwork and shared problem-solving. Emphasise experiential learning, allowing active engagement with design principles through hands-on activities.
	Teaching Experience: Initiate a discussion on principles of design, laying the foundation for subsequent activities. Engage learners in a hands-on building activity, applying principles of design to create the "new thing." Encourage learners to define, customise and communicate the purpose, modifying it based on discussions. Facilitate discussions and presentations where learners communicate the defined, customised use of the "new thing" and share their understanding of argument and proof.
	Learning Experience: Provide a dynamic learning experience through pair work and experiential activities. Foster a creative learning experience where learners define, customise and communicate the purpose of the "new thing" while modifying it based on discussions.

	Enhance understanding of argument and proof through discussions and presentations, promoting effective communication and critical thinking competencies
Learning opportunity 7 and 8: Coding Proficiency for Straight and Turning Movements	
Competencies	1. Coding proficiency for straight and turning movements. 2. Modification of the Hopper into a driving base. 3. Creation of a programming code for making the Hopper move straight.
Assessment opportunities	**Goal:** Evaluate learners' coding competencies and their ability to modify and create programming codes for the Hopper's movements.
	Assessment tool: Utilise modified Hopper designs and programming coded instructions to assess learners' proficiency.
	Type of Assessment: Formative assessment during pair work and collaboration, and summative assessment through exploration learning activities and achievement of specified outcomes.
Learning opportunities	**Facilitating Learning:** Organise learners into pairs, fostering collaborative learning. Encourage collaborative learning beyond individual pairs.
	Teaching Experience: Guide learners in coding exercises for straight and turning movements.

	Facilitate the modification of the Hopper into a driving base. Instruct learners on creating a programming code for straight movements.
	Learning Experience: Emphasise exploration learning, allowing learners to actively experiment with coding constructs.
Learning opportunity 9: Efficient Organisation and Packing of LEGO® Spike Prime™ Robotic Sets	
Competencies	1. Efficient organisation and packing of LEGO® Spike Prime™ robotic sets. 2. Application of Whole Brain® thinking strategies.
Assessment opportunities	**Goal:** Assess learners' ability to organise and pack LEGO® Spike Prime™ robotic sets efficiently using Whole Brain® thinking strategies.
	Assessment tool: Utilise observations, feedback and reflections to assess proficiency.
	Type of Assessment: Formative assessment during pair work and collaboration, and summative assessment based on organised sets' efficiency.
Learning opportunities	**Facilitating Learning:** Organise learners into pairs, encouraging shared responsibility. Promote collaboration beyond individual pairs.

	Teaching Experience: Guide learners in hands-on activities to pack and organise LEGO® Spike Prime™ robotic sets. Encourage collaboration between pairs and sharing Whole Brain® thinking strategies.
	Learning Experience: Provide a dynamic learning experience through pair work and collaboration. Emphasise exploration learning, allowing learners to experiment with Whole Brain® thinking strategies.
Learning opportunity 10: Coding Proficiency for Basic Movement and looping	
Competencies	1. Coding proficiency for basic movement and looping. 2. Application of coding constructs for geometric shapes.
Assessment opportunities	**Goal:** Evaluate learners' coding competencies in creating movement patterns using loops and applying coding constructs to form geometric shapes.
	Assessment tool: Utilise programming coded instructions, geometric shapes created and learner reflections.
	Type of Assessment: Formative assessment during pair work and collaboration, and summative assessment based on specified outcomes.

Learning opportunities	**Facilitating Learning:** Organise learners into pairs, encouraging teamwork. Promote collaboration beyond individual pairs.	
	Teaching Experience: Guide learners in coding exercises for basic movement and looping. Introduce the construct of looping, guiding learners in understanding and implementing loops.	
	Learning Experience: Provide a dynamic learning experience through pair work and collaboration. Emphasise exploration learning, allowing learners to actively experiment with coding constructs.	
Learning opportunity 11: Proficiency in the application of the Design Process		
Competencies	1. Proficiency in the application of the design process. 2. Integration of knowledge from previous learning opportunities into the design, building and coding of a "mini car".	
Assessment opportunities	**Goal:** Evaluate learners' ability to apply the design process and integrate knowledge into designing, building and coding a "mini car."	
	Assessment tool: Utilise design documentation, the functioning prototype and reflections.	
	Type of Assessment: Formative assessment during pair work and collaboration, and summative assessment based on specified outcomes.	

Learning opportunities	**Facilitating Learning:** Organise learners into pairs, encouraging shared problem-solving. Promote collaboration beyond individual pairs.
	Teaching Experience: Guide learners through various stages of the design process. Facilitate the application of coding knowledge gained from previous learning opportunities.
	Learning Experience: Provide a dynamic learning experience through pair work and collaboration. Emphasise exploration learning, allowing learners to actively engage in the design process.
Learning opportunity 12 – 18: Engineering and Design Competencies	
Competencies	1. Learners will demonstrate proficiency in conceptualising, planning and designing a functional miniature golf course or simulated pet prototype, considering structural stability, aesthetics and user interaction. 2. Coding Proficiency: Learners will acquire and apply coding competencies to program the LEGO® Robotics set, enhancing the functionality and interactivity of their projects. 3. Critical Thinking and Problem Solving: Learners will encounter and address challenges during the planning, building and coding phases, fostering critical thinking and problem-solving competencies in a real-world context. 4. Environmental Awareness: Learners will gain an understanding of the importance of sustainability by incorporating recyclable

materials into their projects, promoting eco-friendly practices in their designs.

5. Teamwork and Collaboration: Learners will collaborate in small groups, fostering teamwork and effective communication to successfully plan, build, program code and present their projects.
6. Presentation Competencies: Learners will develop and demonstrate effective presentation competencies, articulating their design rationale, coding processes and overall project execution to peers and educators.
7. Integration of Technology: Learners will integrate technology, specifically the LEGO® Robotics set and hub, into their projects, gaining a practical understanding of how technology can enhance creativity and functionality.
8. Iterative Design Process: Learners will engage in an iterative design process, refining and improving their prototypes based on testing outcomes, reinforcing the importance of continuous improvement in problem-solving.
9. Creativity and Innovation: Learners will express creativity in designing and building their projects, fostering an innovative mindset by exploring novel solutions to design challenges.
10. Subject Specific Knowledge: Depending on the chosen project (miniature golf course or simulated pet), learners may gain subject specific knowledge in areas such as physics (for the golf course) or behavioural science (for the simulated pet).
11. Time Management: Learners will develop time management competencies by adhering to the seven-week project timeline, ensuring timely completion of planning, building, coding, testing and presentation phases.

Assessment opportunities

Goal:

Evaluate learners':

1. ability to apply engineering and design competencies
2. coding proficiency
3. critical thinking and problem-solving
4. environmental awareness
5. teamwork and collaboration
6. presentation competencies
7. integration of technology
8. iterative design process
9. creativity and innovation
10. time management

Assessment tool:

Utilise design documentation, the functioning prototype and reflections.

Type of Assessment:	**Criteria:**
Rubric Evaluation for engineering and design competencies (as illustrated in appendix D)	Structural Stability, Aesthetics, User Interaction
Rubric for programming, Code Review and Execution (as illustrated in appendix D)	Correctness, Efficiency, Creativity
Problem Solving Scenarios	Approach, Analysis, Solution
Material Usage log	Recyclable Materials, Eco-friendly Practices
Presentation Rubric (as illustrated in appendix D)	Clarity, Content, Delivery

	Technology Integration Checklist	Effective Use, Integration with Design, Technical Competence
	Design Iteration Report	Identified Issues, Solutions Implemented, Overall Improvement
	Creative Design Evaluation	Novelty, Innovation, Expressiveness
	Timeline Adherence Record	Adherence to Milestones, Time Allocation, Completion
Learning opportunities	**Facilitating Learning:** Organise learners into pairs, encouraging shared problem-solving. Promote collaboration beyond individual pairs.	
	Teaching Experience: Guide learners through various stages of the design process. Facilitate the application of coding knowledge gained from previous learning opportunities.	
	Learning Experience: Provide a dynamic learning experience through pair work and collaboration. Emphasise exploration learning, allowing learners to actively engage in the design process.	

Note. The table outlines a series of structured learning opportunities for Grade 4 learners, focusing on developing competencies in LEGO® Robotics, coding, and engineering design. Each activity is designed to build skills such as basic mechanics, problem solving, and prototype development, with assessments integrated to monitor both ongoing progress and final outcomes. Teaching strategies emphasise hands-on, collaborative, and exploratory learning, fostering critical thinking, creativity, and teamwork. The final project involves designing and coding a functional prototype, with evaluations covering technical accuracy, innovation, sustainability, and time management, effectively preparing students for future challenges in robotics and engineering.

4.5 Conclusion

The narrative explored particular research questions, analysing essential components of the needs analysis and emphasising their congruence with the overarching objectives of the phase 1 and 2 of the curriculum development process. The initial stage, known as needs analysis, thoroughly examined the requirements of the school and the characteristics of the learners, with a focus on the school's proactive approach to addressing any discrepancies with the suggested curriculum. Fourteen Grade 4 learners with diverse cultural backgrounds were systematically divided into groups in order to facilitate effective interviews and observations. The situation analysis provided a comprehensive overview of the robotics classroom arrangement, the availability of resources and the protocols followed by the organisation. It highlighted the improvements made in the allocation of resources during Term 1.

The second phase, known as backward design, involved presenting the implementation in a highly detailed manner using a carefully structured table. The table was used to clearly demonstrate the intricate relationship between competencies, assessment opportunities, learning opportunities and teaching opportunities. This framework prioritises the deliberate and strategic coordination of learning goals, assessment opportunities and methods of facilitating learning, highlighting intentional alignment.

This chapter has established a strong and solid basis for the following research stage, offering valuable insight into the complexities of the action research design. The acquired insights will have a crucial impact on the continuous development and improvement of the curriculum.

5. CHAPTER 5: NAVIGATING THE EDUCATIONAL ODYSSEY: UNVEILING INSIGHTS THROUGH ACTION RESEARCH CYCLES

5.1 Introduction

"In the middle of difficulty lies opportunity." Albert Einstein (Freeman, 2010)

Albert Einstein's words resonate deeply with the essence of this doctoral research endeavour. The task of developing an action research-driven Whole Brain® coding and robotics curriculum for Grade 4 learners was not without its challenges. Yet, within those challenges lay a unique opportunity to have developed an educational framework that sought to equip Grade 4 learners with a comprehensive set of Whole Brain® thinking competencies. This chapter presents the rigorous journey wherein theoretical knowledge and practical application have intersected to develop an educational framework that seeks to equip Grade 4 learners with a comprehensive set of Whole Brain® thinking competencies. Herein, I present the carefully curated findings, poised to revolutionise the way I approach coding and robotics education in Grade 4.

A comprehensive and multifaceted collection of data has been collected by employing a diverse array of data collection methods, including observations, the Herrmann Brain Dominance Instrument®, photo voicing and photo evidence, text analysis, semi-structured interviews, field notes, reflective journaling, document analysis, text analysis, informal discussions and demonstrations; comprehensive and multifaceted data has been collected. The incorporation of various sources of data formed the fundamental basis for developing my comprehension of the effectiveness and consequences of this educational framework.

Through rigorous examination, I sought to distil meaningful patterns, uncover emergent themes and draw connections across various dimensions of the learning opportunities. Furthermore, I employed a triangulation approach, synthesising findings from multiple sources, thereby enhancing the robustness and validity of my interpretations.

As I navigate through this analytical journey, it is my intention to shed light on the nuanced interplay between cognitive processes, teaching opportunities and learner engagement within the context of Whole Brain® coding and robotics education. By scrutinising the data through a holistic lens, I endeavoured to unearth valuable insights that not only contribute to the advancement of educational theory and practice, but also offer recommendations for the refinement and implementation of the prototype curriculum.

5.2 Participant demographic information

In this section, I delve into a comprehensive overview of the individuals who actively participated in Phase 3 of the action research process. Understanding the demographic composition of my participants was vital for gaining insights into the diverse backgrounds, experiences, and perspectives that contributed to the richness of my study. This section serves as a crucial foundation for interpreting the results and findings presented in subsequent sections, offering a nuanced understanding of the contextual factors that may have influenced the outcomes of the research. By examining the demographic characteristics of my participants, I aimed to provide a holistic portrayal of the sample involved, enhancing the transparency and applicability of the outcomes of the research.

5.2.1 Learner demographics

The study participants' demographic profile is outlined as follows: The 16 participants had noticeable linguistic diversity. More precisely, out of the total participants, seven individuals reported English as their main home language, one participant stated Mandarin as his primary linguistic background, and the remaining individuals primarily communicated in a multilingual environment, including isiZulu, Sesotho and Tswana. All participants were in Grade 4, indicating a uniform academic level. The participants' age range was evenly distributed, spanning from 9 to 10 years old. The collective cohort consisted of 16 participants, with 6 identified as female and 10 as male, indicating a balanced gender distribution within the sample. This extensive analysis of participant demographics provided a fundamental understanding for further analyses within the study framework.

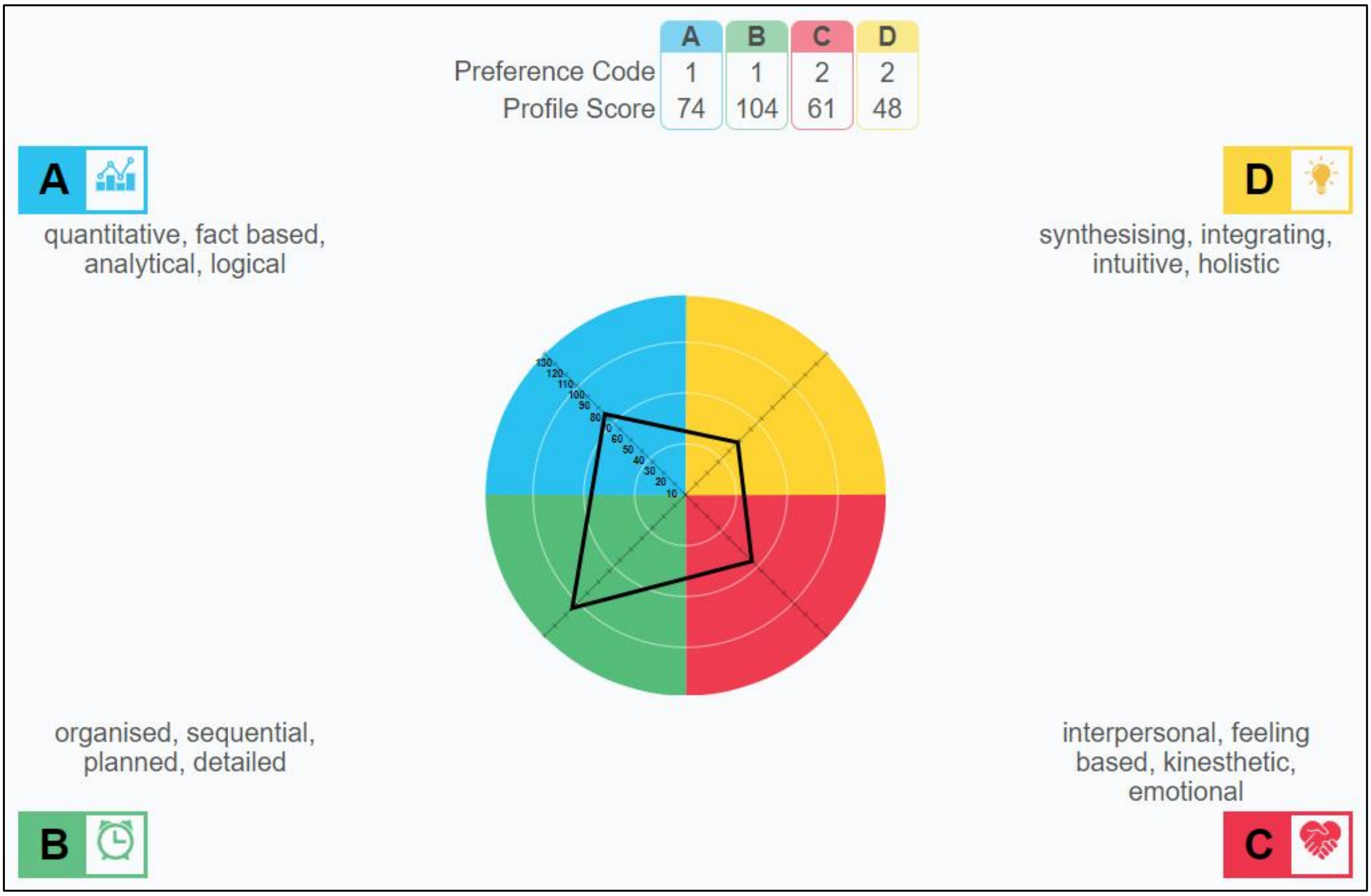
5.2.2 My thinking preference

I begin this section by presenting my own HBDI® profile, which has served as the initial step in my personal reflective journey. The HBDI® was used to identify my thinking preferences and shed light on my strengths and areas for growth. This self-awareness of my thinking preferences, strengths and areas for growth has not only enhanced my individual decision-making processes but has also proven invaluable in classroom settings.

My thinking preferences are visually depicted in Figure 10, with a double HBDI® profile (Herrmann International, 2018). Notably, my preferences predominantly align with the A and B quadrants. According to the results of the HBDI®, my cognitive preferences align with a thinking style that is characterised by conservatism, sequential thinking, meticulous attention to detail, and a preference for organisational structure (Herrmann International, 2018). This alignment is reinforced in section 4.3.1, where practical examples underscore my cognitive inclinations, particularly evident in the meticulous organisation of the storeroom. This real-world application vividly illustrates the embodiment of my cognitive preferences, as identified by the HBDI® results (Herrmann International, 2018).

Figure 10

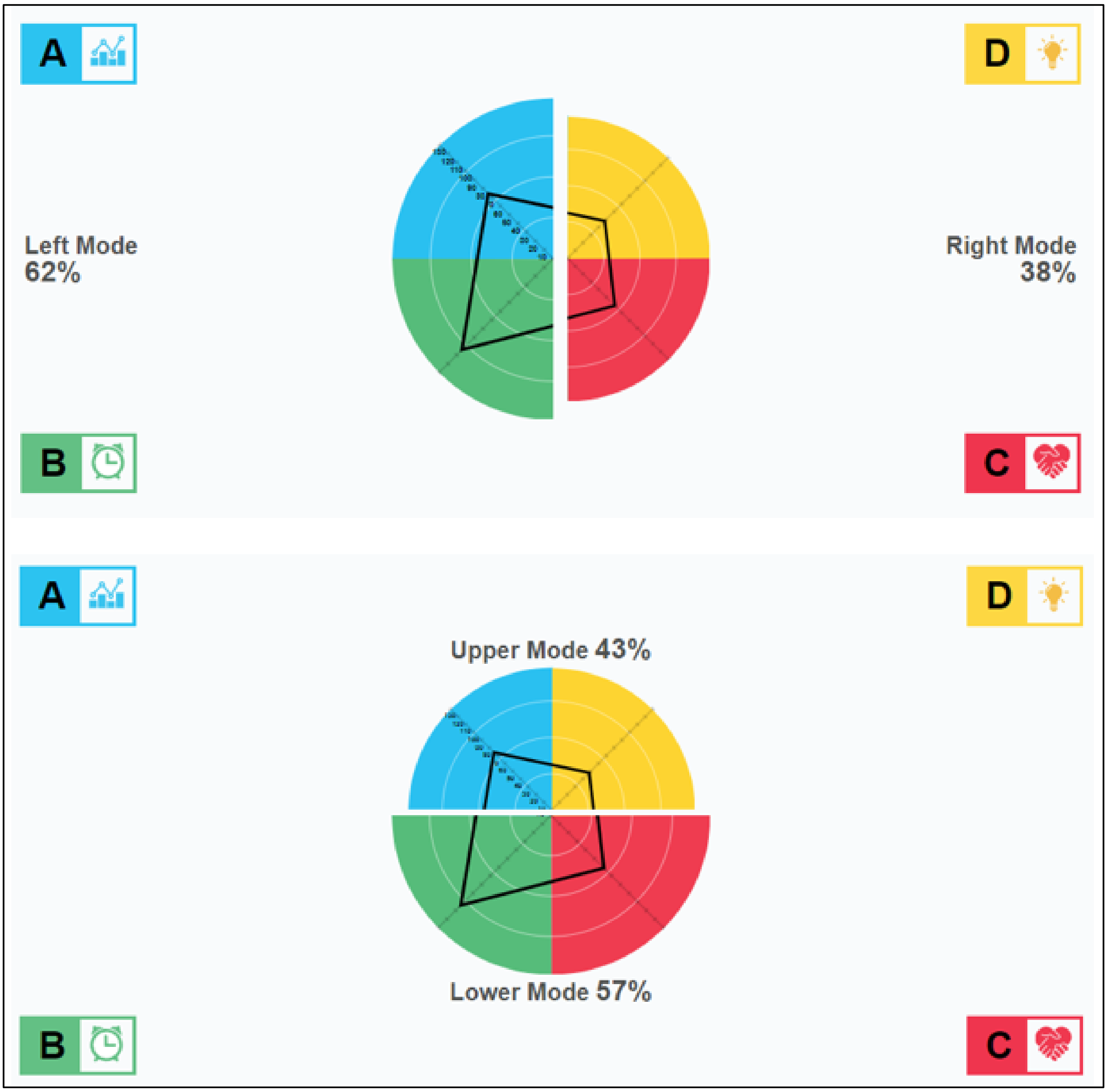
My HBDI® profile summary



In accordance with the HBDI®, my thinking preference profile shows a main inclination towards left mode thinking (as illustrated in Figure 11 below). Left mode thinking is characterised by a preference for detailed, efficient and rational cognitive processes associated with the A and B quadrants (Herrmann International, 2018). The left mode consists of these quadrants, which prioritise analytical and structured thinking. In contrast, the C and D quadrants, which make up the right mode, emphasise intuitive, expressive and idealistic tendencies (Herrmann International, 2018).

Figure 11

My detailed HBDI® profile



My cognitive preferences also suggest a stronger tendency towards lower mode thinking, which is characterised by a preference for instinctive and visceral thought processes found in the B and C quadrants (Herrmann International, 2018). The preference for the lower mode is evident in a strong inclination towards practical and experiential thinking, as opposed to the abstract and theoretical cognitive styles associated with the A and D quadrants, which together form the upper mode (Herrmann International, 2018).

As a researcher, I primarily rely on lower left mode thinking, which means I have a cognitive style that is characterised by a practical and hands-on approach to engaging with information (Benziger, 2013). This cognitive preference significantly shapes the way I approach qualitative research, influencing both my strengths and potential challenges throughout the research process.

Lower left mode thinking is characterised by its strong focus on the practical implementation of research findings (Benziger, 2013; Herrmann Global LLC, 2016; Herrmann International, 2018). This suggests that I have a natural tendency to carefully think about and give importance to the practical consequences of my research. I make sure that the results are not limited to academic contexts but are focused on offering practical insights that can be successfully implemented in real-life situations.

In addition, adopting a lower left mode of thinking enables a natural and deep comprehension of the real-life encounters of individuals involved in research (Benziger, 2013; Herrmann Global LLC, 2016; Herrmann International, 2018). My cognitive style allows me to deeply understand and connect with the practical challenges and experiences of individuals, which enhances the quality and depth of my qualitative exploration.

Nevertheless, this cognitive inclination presents a series of difficulties. There is a possibility of placing too much importance on practical applications and neglecting theoretical complexity (Benziger, 2013; Herrmann Global LLC, 2016; Herrmann International, 2018). While the focus on immediate applicability is a strength, it may lead to a neglect of deeper theoretical considerations, impacting the conceptual richness of the research. Moreover, the tendency to avoid conceptual and theoretical cognitive styles can create difficulties when addressing abstract or theoretical elements of qualitative research. This necessitates extra effort and careful consideration when engaging with intricate frameworks or conceptual discussions.

The combination of left mode and lower mode thinking in my cognitive profile results in a well-rounded and varied approach to qualitative research (Benziger, 2013; Herrmann Global LLC, 2016; Herrmann International, 2018). Left mode thinking, characterised by analytical depth, critical thinking and systematic data analysis, emphasises rigorous examination of information. On the other hand, lower mode thinking focuses on the practical and real-world application of research findings. This combination facilitates a thorough investigation of research inquiries, encompassing both profound theoretical analysis and tangible practical consequences (Benziger, 2013; Herrmann Global LLC, 2016; Herrmann International, 2018).

To summarise, my strong inclination towards lower left mode thinking has advantages in practical implementation and comprehension of real-life experiences. However, it is important to maintain a delicate equilibrium to ensure theoretical depth in qualitative research endeavours. The integration of left and lower left mode thinking offers a comprehensive and balanced approach to qualitative investigation.

5.3 Phase 3: Action research cycles

This section provides an overview of the action research cycles conducted during the course of this study, which encompassed three terms. This section comprises a comprehensive collection of fourteen distinct cycles, each encompassing a singular learning opportunity, thereby presenting a diverse range of learning opportunities. Each cycle represents a concise yet comprehensive research process that informs the subsequent cycle. The cycles described in this process document the progression of my teaching and learning opportunities and the dynamic relationship between theory and practice, starting from the early planning stages and concluding with reflective analysis. By means of thorough documentation and rigorous analysis, this section sheds light on the gradual development, obstacles overcome and knowledge acquired, resulting in a nuanced comprehension of the iterative characteristics inherent in the process of learning. The cycles took place as follow:

5.3.1 Cycle 1: Introduction to LEGO® blocks and basic mechanics

5.3.1.1 Planning for transformation

The lesson offered a preliminary investigation into constructing structures using elementary blocks and essential mechanical principles. Learners examined the functions of each component and were assigned the task of conceptualising real-world situations in which these components were practically applied. The learning opportunities were as follow:

- Switching the hub on and off
- Creating a picture on the hub using the lights on the hub
- Connecting a motor for the hub and programming the hub to turn
- Connecting a colour sensor for the hub and programming it to make a sound when detecting a certain colour
- Connecting a distance sensor to the hub and programming the hub to make a sound when an object is within a certain distance of the hub
- Connecting the pressure sensor to the hub and programming the hub to start the motors when pressed
- Using the hub as a gyro sensor and programming the hub to make a sound then held at an angle
- Combining the components to create a functioning robot

5.3.1.2 Acting to transform

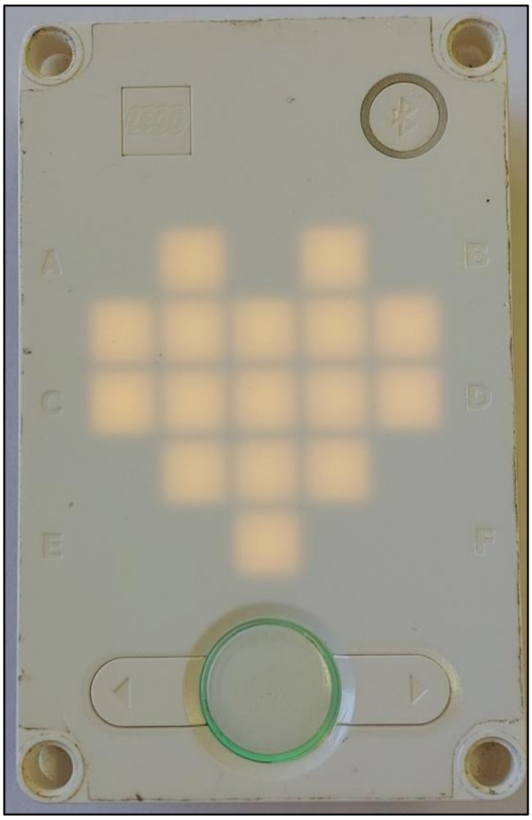
The learners were grouped into teams of three to engage in practical tasks designed to apply each learning component effectively. These tasks incorporated a blend of learner led instruction and discovery learning, utilising various sensors and modules. Photo evidence 4, in the next section, provides visual examples of the six different sensor and module types.

Creating a picture on the hub using the lights on the hub

Photo evidence 4 shows the Light Matrix, a yellow rectangular module designed with numerous small squares, each representing a light. This component was also referred to as the "hub" among the learners. Within LEGO® Spike Prime™ sets, the hub functioned as the central control unit, serving as the cognitive centre of the robotics system (The knowledge hub, 2024). It acted as an intermediary between the tangible elements of the robot, such as motors and sensors, and the programming that dictated their actions. The hub featured multiple ports enabling the connection of sensors and motors, thereby facilitating the development of intricate robotic systems. Additionally, it contained a rechargeable battery to ensure continuous power supply during the robot's operation. Through programming, learners could instruct the hub to manipulate the motion of motors, obtain input from sensors and execute predetermined sequences of actions, thereby enabling the robot to accomplish various tasks and functions. Overall, the hub played a crucial role in enabling the functionality and adaptability of LEGO® Spike Prime™ robots.

Photo evidence 4

The light matrix



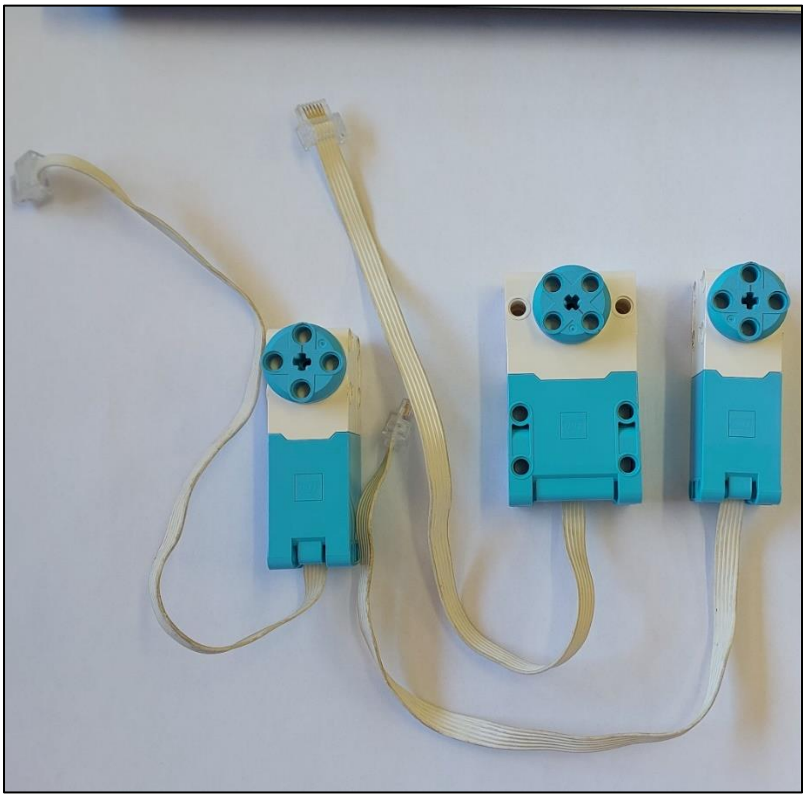
At this point in the lesson, learners were challenged to make different pictures using the light matrix, which encouraged them to engage in creative problem-solving and innovative thinking. This activity fostered relational thinking (quadrant C) as learners collaborated and exchanged ideas to generate various patterns and images on the light matrix. By exploring the capabilities of the light matrix and experimenting with different configurations, learners developed a deeper understanding of spatial relationships and visual representation. Additionally, this hands-on activity promoted experiential learning (quadrant D) as learners actively manipulated the light matrix to create unique designs, enhancing their comprehension of programming concepts and strengthening their problem-solving competencies. Through this interactive exercise, learners cultivated a culture of exploration, creativity and adaptability, aligning with the principles of the HBDI® framework and fostering holistic cognitive development.

Connecting a motor to the hub and programming it to turn

Photo evidence 5 depicted three motors. These motors were characterised by a blue cubic design with a white top, intended for motion activities (The knowledge hub, 2024). Among them, there are two small motors and one large motor, with the large motor positioned in the centre of Photo evidence 5. In LEGO® Spike Prime™ sets, the two small motors and one large motor served various functions in creating and controlling robotic movements (The knowledge hub, 2024). The small motors were typically used for tasks that required precise and subtle movements, such as controlling the rotation of small components or making minor adjustments to the robot's position (The knowledge hub, 2024). The large motor, on the other hand, was more powerful and was often utilised for tasks that required greater strength or larger scale movements (LEGO® Education, 2022). Due to its size and strength, the big motor was well suited for powering larger mechanisms or driving the primary movements of the robot.

Photo evidence 5

Motors



The learners were presented with the cognitive challenge of integrating the motors with the Hub and subsequently devising a programmed algorithm through the application interface on the computer to initiate motor movement. This task engaged their cognitive faculties, invoking analytical thinking (quadrant A) as they navigated the technical intricacies of motor connectivity and operational programming.

Connecting a colour sensor to the hub and programming it to make a sound when detecting a certain colour

Photo evidence 6 displays the colour sensor, a small square shaped sensor with a central lens, coloured black. In LEGO® Spike Prime™ sets, this sensor plays a crucial role in detecting and recognising colours within its field of view (The knowledge hub, 2024). Capable of identifying various colours, such as red, green, blue, yellow, white and black, the colour sensor enables the robot to respond to its surroundings based on colour cues. This functionality enhanced the robot's ability to perform tasks like following coloured paths, sorting objects or reacting to specific colours in interactive challenges or games.

Photo evidence 6

Colour sensor

The learners were given the challenge of connecting the colour sensor to the hub, and they then had to create a program using the computer application. With the guidance given, they assumed responsibility for the process and created a code designed to identify a specific colour and activate a corresponding sound. This exercise exemplified a learner centred approach, promoting a feeling of independence and authority as individuals worked through the complexities of combining hardware and programming software.

Connecting a distance sensor to the hub and programming it to make a sound when an object is within a certain distance of the hub

Photo evidence 7 displayed the distance sensor, which is identifiable by its black, rectangular shape. The primary purpose of the distance sensor in the LEGO® Spike Prime™ sets is to accurately gauge the distances between the sensor itself and nearby objects (The knowledge hub, 2024). The distance sensor offers valuable input for programming the robot's behaviour. The robot is capable of detecting obstacles, manoeuvring around obstacles and maintaining a predetermined distance from objects (The knowledge hub, 2024).

Photo evidence 7

Distance sensor

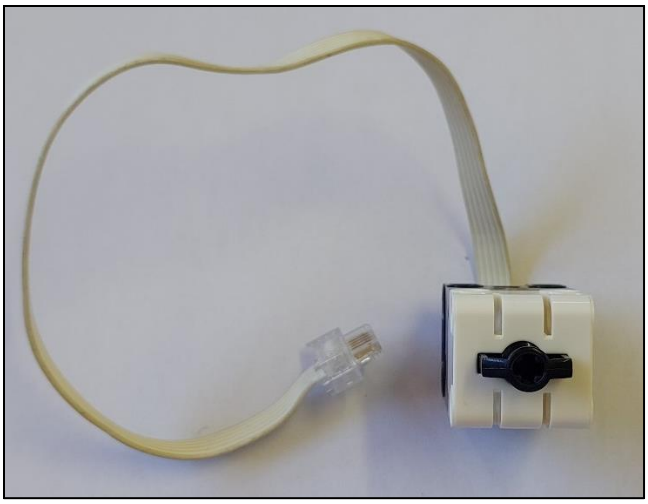
At this point of the learning opportunity, learners had to connect the distance sensor to the hub. They then had to create a programme to prompt the hub to emit a sound upon detection of an object within a predefined distance range by the distance sensor. This process primarily engaged learners in analytical thinking (quadrant A) as they meticulously analysed the functionalities of the distance sensor and devised logical programming sequences to trigger the desired response from the hub. Additionally, practical thinking (quadrant B) was involved as learners translated their technical knowledge into actionable steps, effectively executing the connection process and programming tasks to achieve the desired outcome.

Connecting the pressure sensor to the hub and programming it to start the motors when pressed

Photo evidence 8 displayed the Force Sensor, distinguished by its white cubic structure. The Force Sensor offers crucial input for programming the robot's behaviour in diverse applications. For instance, it could be utilised to identify the moment an object was held or pressed, enabling the robot to execute actions like grasping objects with a specific degree of force or reacting to variations in pressure (The knowledge hub, 2024).

Photo evidence 8

Force sensor



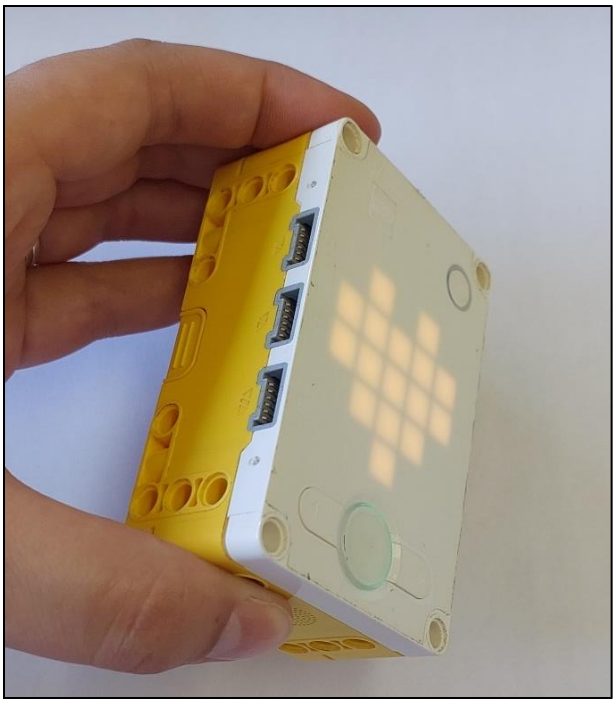
At this stage of the lesson, learners were tasked with connecting the force sensor and a motor to the hub. Subsequently, they were instructed to utilise the force sensor as a button, whereby pressing the sensor would activate the motor to turn. This activity requires learners to engage in both practical and analytical thinking. Practical thinking (quadrant B) was necessary as learners executed the physical connection between the force sensor and the motor to the hub, demonstrating their technical proficiency in assembling the components. Analytical thinking (quadrant A) was employed as learners devised the programming logic necessary to translate the sensor input (pressing the force sensor) into a specific action (turning the motor). Through this process, learners demonstrated their ability to integrate hardware components with programming logic to achieve a functional outcome.

Using the hub as a gyro sensor and programming the hub to make a sound then held at an angle

Photo evidence 9 displays the Gyro Sensor, symbolised by hand gestures indicating motion. This sensor was commonly employed to quantify orientation or rotation (The knowledge hub, 2024). The Gyro Sensor in LEGO® Spike Prime™ sets are utilised to precisely gauge the orientation and rotational movement of the robot (The knowledge hub, 2024). The function of this sensor was to perceive alterations in the robot's orientation with respect to its initial position or a designated reference point, thereby enabling accurate regulation of motion and navigation.

Photo evidence 9

Gyro sensor



Learners were tasked with crafting a program designed to prompt the hub to emit a sound when it was held at a specific angle. This activity engaged learners in a combination of analytical and experimental thinking. Analytical thinking (quadrant A) was employed as learners analysed the sensor data related to the hub's orientation and devised logical conditions to trigger the sound output based on angle readings. Meanwhile, experimental thinking (quadrant D) was fostered as learners explored different angles and tested various configurations to determine the optimal threshold for activating the sound. Through this iterative process of analysis and experimentation, learners enhanced their problem-solving abilities and deepened their comprehension of sensor integration and programming logic.

Combining the components to create a functioning robot

The subsequent task entailed the amalgamation of all the lessons learned, culminating in the synthesis of various components to construct a fully functional robot. Learners were challenged to integrate the hub, the light matrix, motors, pressure sensor and potentially other elements to engineer a robot capable of performing specific tasks or functions. This task required learners to employ a holistic approach to problem-solving, drawing upon their acquired knowledge and competencies across multiple domains. By combining hardware components with programmed instructions, learners engaged in experiential learning (quadrant D), actively applying theoretical concepts in a practical context to achieve tangible outcomes. Additionally, this task promoted relational thinking (quadrant C) as learners collaborated and coordinated their efforts to assemble and program the robot, leveraging the diverse functionalities of each component to achieve a unified objective. Through this comprehensive and integrative activity, learners demonstrated their ability to synthesise complex concepts and apply them creatively to real world challenges, thereby fostering a deeper understanding of robotics principles and enhancing their problem-solving capabilities.

5.3.1.3 Observing the transformation

Switching the hub on and off

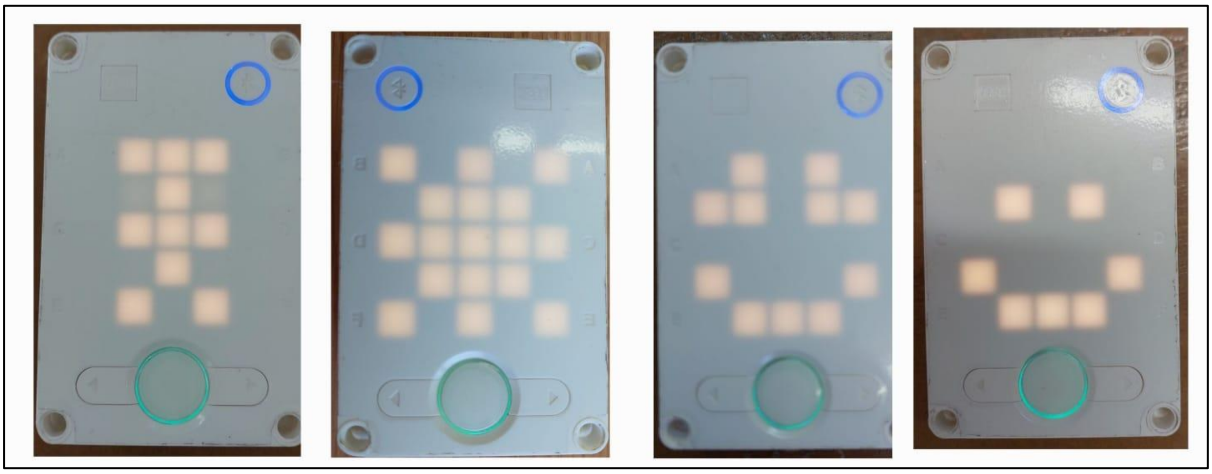
At this point of the learning opportunity, learners demonstrated competence in operating the hub, effectively switching it on and off as instructed. They exhibited practical thinking (quadrant B) as they followed sequential steps to power the hub, displaying an understanding of basic device operation.

Creating a picture on the hub using the lights

As learners utilised lights to create pictures on the hub, they displayed creativity and innovation, demonstrating their capacity for critical and analytical thinking (quadrant A) while applying their technical expertise in real world contexts. By engaging in practical experimentation, learners investigated the capabilities of the light matrix, promoting experiential learning (quadrant D) and stimulating their ability to think creatively. Certain groups exhibited exceptional ingenuity by creating elaborate designs, including smiley faces, and other intricate patterns (as illustrated in Photo evidence 10).

Photo evidence 10

Compilation of pictures on the hub



Their artistic goals are achieved through a holistic cognitive approach that integrates analytical, practical and relational thinking (quadrants A, B, and C), demonstrating a high level of creativity. Some individuals chose to take a more utilitarian approach by devising terms such as "Go" or basic geometric figures. This showcases their capacity to adjust their strategy according to the demands of the task, highlighting their flexibility and adaptability (quadrant C). The various creations demonstrate the flexibility of the light matrix and the learners' capacity to utilise their imagination and technical abilities to achieve their intended results. In summary, this activity served as a platform for both artistic expression and the reinforcement of programming and robotics concepts. It was engaging and interactive, in line with the principles of the HBDI® framework and promoted holistic cognitive development.

Connecting a motor to the hub and programming it to turn

Learners successfully connected a motor to the hub and programmed it to turn, showcasing their technical proficiency and problem-solving competencies. Through a combination of practical thinking (quadrant B) and analytical reasoning (quadrant A), learners effectively manipulated the motor's rotation and direction, achieving the desired outcome.

Connecting a colour sensor to the hub and programming it to make a sound

During this activity, learners adeptly connected a colour sensor to the hub and programmed it to make a sound when detecting a certain colour, showcasing their proficiency in practical problem-solving and technical execution. Engaging in hands-on experimentation, learners explored the functionalities of the colour sensor, fostering experiential learning (quadrant D) and encouraging them to explore different programming possibilities. They demonstrated relational thinking (quadrant C) as they integrated sensor input with programmed responses, enhancing their understanding of cause and effect in robotics. Notably, learners exhibited creativity and innovation by trying different sounds for different colours, such as meowing for red and barking for blue. This experimentation not only reinforced their understanding of programming concepts but also encouraged them to think critically and adapt their approaches based on sensor feedback. Overall, this activity provided a dynamic learning experience that combined technical skill development with creative problem-solving, aligning with the principles of the HBDI® framework and fostering holistic cognitive development.

Connecting a distance sensor to the hub and programming it to make a sound

At this point in the lesson learners demonstrated proficiency in connecting a distance sensor to the hub and programming it to emit a sound when an object was within a certain range, showcasing their technical acumen and problem-solving competencies. Engaging in analytical thinking (quadrant A) and experimental exploration (quadrant D), learners effectively calibrated the sensor's parameters to trigger the desired response. Notably, learners encountered the challenge of changing the distance units from inches to meters. Overall, the activity provided a valuable opportunity for learners to deepen their understanding of sensor functionality and programming concepts while fostering a mindset of adaptability and resourcefulness.

Connecting the pressure sensor to the hub and programming it to start the motors

As learners connected the pressure sensor to the hub and programmed it to initiate motor activity upon being pressed, they demonstrated a practical application of sensor input in robotics. This activity fostered experimental thinking (quadrant D) as learners explored the sensor's functionality and its interaction with other components.

Using the hub as a gyro sensor and programming it to make a sound

Learners adeptly utilised the hub as a gyro sensor, programming it to emit a sound when held at an angle, showcasing their proficiency in sensor data interpretation and programming logic. Engaging in practical experimentation and iterative problem-solving, learners explored various angles and corresponding sound triggers, demonstrating their capacity for creative exploration and adaptability. Notably, learners experimented with different sounds, leveraging their creativity and imagination to customise the auditory feedback based on the gyro sensor's readings. This activity encourages learners to think critically about the relationship between sensor inputs and programmed responses, fostering analytical thinking (quadrant A) and experimental exploration (quadrant D). Overall, the hands-on nature of the task provided learners with valuable opportunities to deepen their understanding of sensor functionality and programming concepts while promoting a mindset of curiosity and innovation.

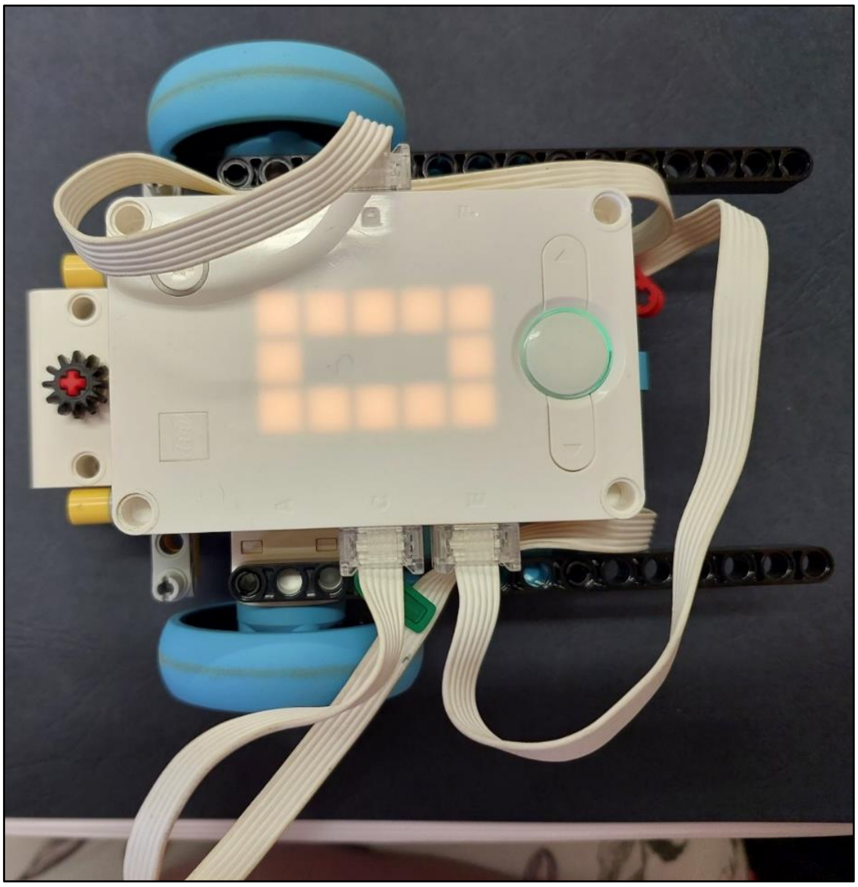
Combining the components to create a functioning robot

Finally, learners combined the components to create functioning robots, showcasing their ability to integrate various sensors and motors into a cohesive system. This activity promoted holistic thinking (quadrant B) as learners synthesised their knowledge and competencies to achieve a tangible outcome, reinforcing their understanding of robotics principles and applications.

As depicted in Photo evidence 11, most groups decided to build a simple car. Photo evidence 11 depicted one of these basic cars built with the hub, two motors, two blue wheels, the white ball as a third wheel and black components connecting the wheels to the hub.

Photo evidence 11

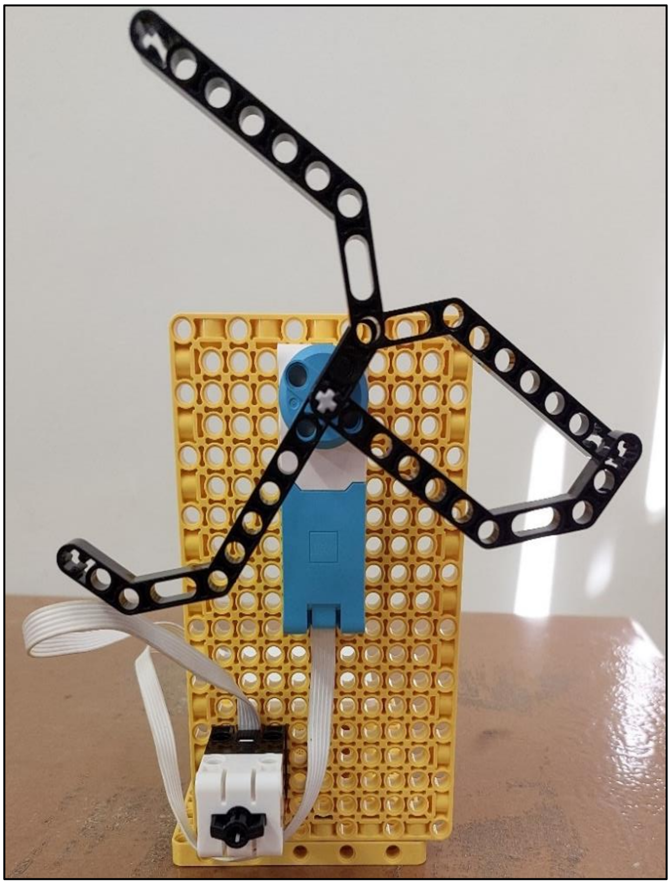
Basic car



One pair built a fan as illustrated in Photo evidence 12. The image shows a yellow perforated board with various components attached to it. There are black structural frames with multiple holes, made of plastic, attached in an irregular pattern to form the blades of the fan. A white motor is used to propel the blades. A pressure sensor is used as a button on the left side of the board. The hub with the programming code on is fixed to the back of the board.

Photo evidence 12

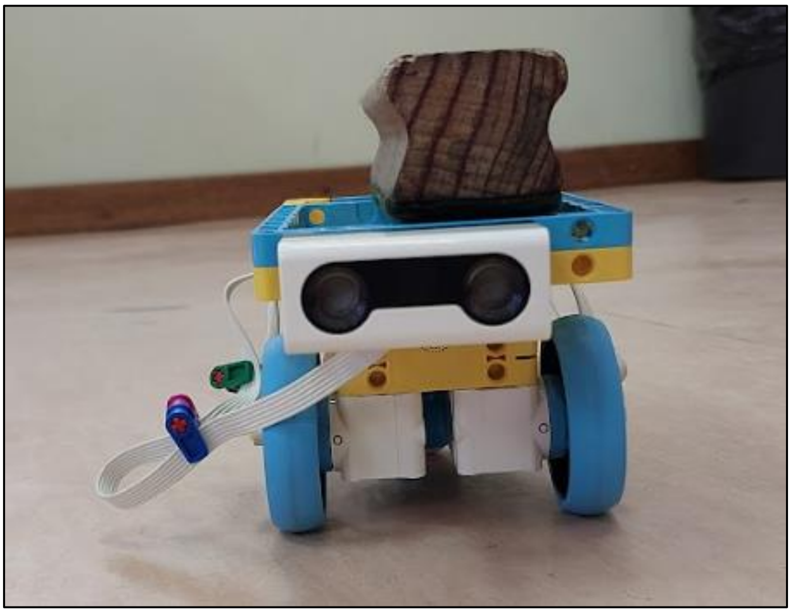
Basic fan



Another pair built a "classroom helper" as illustrated in Photo evidence 13. Photo evidence 13 shows a car built with two motors and four wheels. There is a distance sensor attached to the front to detect when to stop. There is a yellow rectangle on top wherein a white board eraser is placed.

Photo evidence 13

Classroom helper car



Here learners had the chance to utilise both their holistic (quadrant B) and experimental (quadrant D) abilities. Through collaborative teamwork, learners utilised a wide range of perspectives and methods, promoting comprehensive problem-solving and collaborative synergy. This collaborative endeavour enhanced the learning experience and fostered crucial interpersonal competencies necessary for successful teamwork and collaboration in real-life situations.

Furthermore, the focus on practical experimentation and exploration promoted experiential learning, allowing learners to enhance their abilities and improve their comprehension through direct involvement with the materials and concepts. This experiential learning approach aligned with the experimental mindset (quadrant D), cultivating a culture of exploration, innovation and adaptability that was crucial for effectively addressing dynamic and intricate real-world challenges.

Overall Observations

Throughout the practical tasks, learners exhibited a high level of engagement and collaboration, effectively applying their knowledge and competencies to solve complex problems. The hands-on nature of the activities facilitated experiential learning (quadrant D), allowing learners to deepen their understanding through direct interaction with robotics components. Additionally, the integration of group work and discovery learning promoted a holistic approach to learning, fostering cognitive development across multiple domains.

As the educator responsible for offering the learning opportunities, I faced numerous obstacles during this lesson. Initially, because tablets were not accessible, I arranged for learners to use the computer room, which compounded the disruptions for classes that focused on computer related subjects. Moreover, the occurrence of delays in the delivery of new sets led to a decrease in the size of the groups. These factors impacted the dynamics of the learning opportunities and made it necessary for me to be adaptable.

One significant obstacle faced by learners was the absence of cohesive collaboration within groups. Instead of collaborating as a pair, one learner assumed the role of builder while the other learner observed. This method impeded the process of collaborative learning. In addition, certain learners discovered that the projected building steps were insufficiently sized, potentially impeding their capacity to adhere to building instructions with precision.

Notwithstanding these difficulties, a noteworthy advantage was the learners' capacity to articulate steps, demonstrating their expertise in visualising and comprehending the construction procedure.

5.3.1.4 Reflecting on transformation

The lesson provided a comprehensive exploration into the construction of structures using elementary blocks and essential mechanical principles, effectively integrating practical application with theoretical understanding. The learning opportunities encompassed a range of competencies, from basic operational tasks such as switching the hub on and off, to more complex programming challenges like connecting sensors to the hub and programming them to perform specific tasks. The lesson structure, which included group activities, facilitated a dynamic learning environment that catered to diverse thinking preferences and promoted collaborative learning.

One of the key strengths of the lesson was its emphasis on hands-on, experiential learning. By engaging in practical tasks that involved connecting sensors, motors and other components to the hub, learners were able to apply theoretical concepts in a real-world context. This approach not only deepened their understanding of robotics principles but also enhanced their problem-solving and critical thinking competencies. Additionally, the use of group activities encouraged collaboration and communication competencies, essential for future academic and professional endeavours.

However, the lesson also faced several challenges, such as the lack of access to tablets and delays in the delivery of new sets, which impacted the overall learning experience. These challenges necessitated flexibility and adaptability to ensure that the learning objectives were still met. Furthermore, the issue of learners assuming different roles within groups, with one learner taking on the role of builder while the other observed, highlighted the importance of fostering cohesive collaboration within groups.

5.3.2 Cycle 2: Problem solving with colour sensors and storytelling

5.3.2.1 Planning for transformation

The focus of the second cycle revolved around the utilisation of the colour sensor and the development of storytelling construction as problem-solving methodologies by building ‘Kiki’, a robot featured on the Spike Prime™ application.

The learning opportunities are as follows:

- Defining the problem
- Utilising the colour sensor to detect and respond to three colours
- Composing a story utilising sounds and the colour sensor

5.3.2.2 Acting to transform

In the step of implementation learners were divided into groups of three. They were engaged in multifaceted tasks aimed at practical application and cognitive development.

Defining the problem

At the start of this learning opportunity, learners were prompted to employ analytical thinking (quadrant A) by formulating and articulating clear problem statements. This activity started with a discussion on pets, wherein learners were invited to share anecdotes about their pets' behaviours. The focus of the discussion was on identifying potential problems their pets might be experiencing. For instance, learners were encouraged to consider whether their cats had ever emitted unusual sounds or if their dogs exhibited barking or growling behaviours. This process involved identifying specific problems or challenges, conducting an analysis of their underlying factors, and articulating a clear and succinct problem statement that encapsulated the fundamental essence of the issue at hand. By engaging in this activity, learners demonstrated their capacity for logical analysis and critical reasoning, effectively identifying and defining problems within a given context. This analytical approach provided a solid foundation for subsequent problem-solving efforts, facilitating a systematic and structured approach to addressing complex issues. Through the application of analytical thinking competencies, learners were able to clarify the scope and nature of problems, enabling them to devise effective strategies for resolution and innovation.

Utilising the colour sensor to detect and respond to three colours

During this section of the lesson, learners were assigned with demonstrating competence in both practical construction and programming competencies, engaging in experiential learning (quadrant D) as they built the robot 'Kiki' and programmed it to utilise the colour sensor effectively. This involved a blend of hands-on experimentation and guided learning opportunities, enabling learners to apply technical knowledge and problem-solving abilities in a real-world context. By calibrating the colour sensor to accurately identify three predetermined colours and programming the robot to execute pre-programmed reactions (in this case, emitting sounds) based on the identified colours, learners demonstrated their proficiency in relational thinking (quadrant C) by integrating sensor data with programmed responses. Through this process, learners enhanced their understanding of cause-and-effect relationships and honed their competencies in utilising sensors for responsive robotic behaviour. Additionally, by engaging in iterative experimentation and refinement, learners cultivated an experimental mindset, fostering creativity and adaptability in their approach to problem-solving and innovation.

Composing a story utilising sounds and the colour sensor

This section of the lesson involved incorporating auditory signals and events triggered by the colour sensor to improve the progression of the story and captivate the audience in a fully immersive storytelling encounter. The lesson incorporated a comprehensive approach to cognitive preferences as delineated in the HBDI® framework. Learners participated in analytical thinking, specifically in quadrant A, by precisely defining and expressing problem statements. They utilised logical analysis, critical reasoning, and problem-solving abilities to identify fundamental factors and create unambiguous problem statements. In addition, learners exhibited practical cognitive abilities that were in line with quadrant B. They actively participated in hands-on problem-solving activities by configuring and utilising the colour sensor to identify and react to predetermined colours. This allowed them to apply their technical knowledge to real-life situations. Furthermore, this result incorporated aspects of relational cognition (quadrant C) and experimental cognition (quadrant D). Learners demonstrated relational thinking by effectively communicating and engaging in interpersonal relationships using sounds and the colour sensor as storytelling elements in their narratives. Learners engaged in both creativity and innovation to enhance the narrative experience, embodying the principles of experimental thinking, exploration and creativity.

5.3.2.3 Observing the transformation

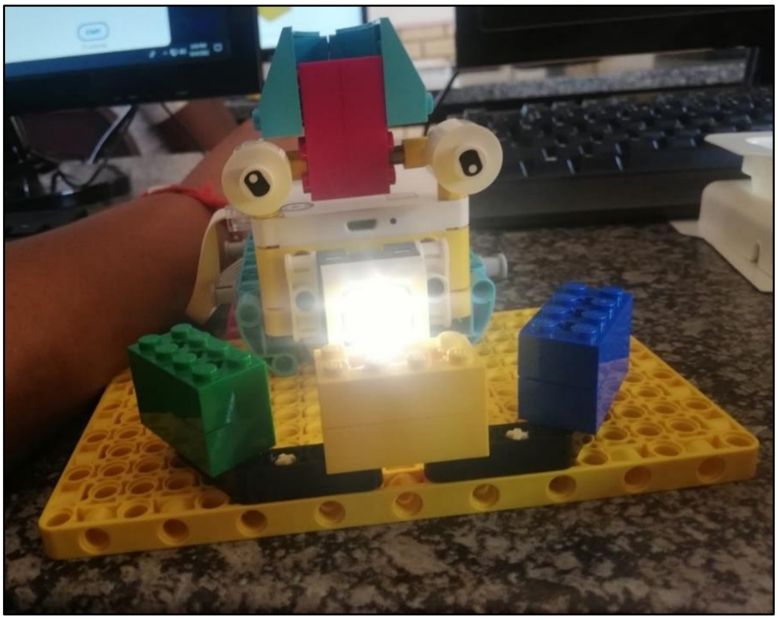
Observation for problem definition outcome

Although tablets were not accessible, learners organised into groups of three, and utilising the computer room, demonstrated remarkable skills in crafting clear problem statements. They actively engaged in the process of identifying multiple challenges, carefully examining the underlying factors that contributed to each issue. Afterwards, the learners skilfully combined their observations into concise and clear problem statements, successfully capturing the fundamental nature of each problem. Their analytical thinking abilities were showcased through their logical analysis and critical reasoning competencies, particularly evident in their construction and coding of the robot 'Kiki' using the Spike Prime™ application.

Photo evidence 12 is a constructed model made from multi coloured LEGO® building blocks. The colour sensor can be seen emitting a light while detecting the coloured blocks. 'Kiki' can move to detect the blocks to the right and the left as well. Photo evidence 12, captured by the learners themselves, serves as a visual documentation of their robotic creations. Learners were tasked with taking pictures of their robots as part of the learning process for several reasons such as documenting their own progress, sharing photos with their peers and the celebration of the completion of their robot.

Photo evidence 14

Complete KIKI



In this narrative exercise, one group crafted a story featuring a character named Kiki embarking on a walk. The narrative was augmented with auditory cues to enhance the storytelling experience. For instance, the introduction of traffic sounds coincided with Kiki's encounter with blue blocks, signifying her surroundings. Subsequently, the appearance of a cat was represented by meowing sounds accompanying the depiction of yellow elements. Lastly, Kiki's response of barking at the cat was portrayed through barking sounds, synchronised with the representation of green elements.

Another group integrated Kiki's backyard playtime into their narrative by incorporating bird chirping sounds when encountering the blue blocks, depicting her outdoor environment. The appearance of a ball was symbolised by the sound of a bouncing ball, enriching the sensory experience. The narrative concluded with Kiki barking at the ball, emphasising her playful interaction with the object.

A third group decided to rename their robot Max. Their narrative included Max navigating the urban landscape, the sounds of cars honking and engines revving filled the air, representing his journey through the city streets marked by blue blocks. Suddenly, Max encounters a towering building, symbolised by the sound of construction work echoing in the distance when he reaches a yellow block. Intrigued by the activity, Max approaches the building and sees a group of workers. The clanking of tools and voices of the workers surround him, immersing him in the scene.

Analysis of colour sensor usage

Through group collaboration and the use of the computer room as an alternative to tablets, learners displayed impressive proficiency in utilising the colour sensor feature in the Spike Prime™ application. They successfully detected and responded to three different colours. By carefully calibrating the sensor, they ensured its accurate detection of specific colours and successfully carried out pre-programmed responses or behaviours based on the colours identified by the sensor. Their practical thinking competencies were demonstrated by their ability to apply technical knowledge to real world situations with accuracy and precision. This was particularly evident in their coding of the 'Kiki' programme, which emitted a sound when it detected a specific colour within the Spike Prime™ application.

Methodology for creating a narrative using auditory elements and the colour sensor result

By working in groups of three and utilising the computer room as an alternative tool, learners demonstrated their creativity and technical skill in crafting stories that were enriched by sounds and the colour sensor feature within the Spike Prime™ application. By seamlessly combining auditory signals and sensor triggered events, they enhanced the narrative progression, effectively captivating the audience in a completely immersive storytelling experience. Their adeptness at incorporating sensory cues and technological elements into storytelling demonstrated their innovative thinking and relational abilities. They effectively communicated ideas and engaged in creative expression to heighten the narrative impact, as exemplified in the storytelling aspect of 'Kiki' in the Spike Prime™ application.

5.3.2.4 Reflecting on transformation

In the step of implementation, learners were divided into groups of three, engaging in multifaceted tasks aimed at practical application and cognitive development. However, in the cycle 1, I experienced difficulties with learners assuming different roles within groups, with one learner taking on the role of builder while the rest watched. To address this challenge in this lesson, I clearly communicated the expectations for group work, emphasising the importance of active participation from all members. I encouraged learners to discuss and decide on roles together, ensuring that everyone felt valued and involved in the process. This approach aimed to foster a more cohesive collaboration within groups and prevent one-sided participation. Despite my efforts to promote equitable participation by encouraging collaborative discussion by learners, the desired outcome of fostering cohesive collaboration within groups and preventing one-sided participation was not fully achieved. There was a need to incorporate opportunities for peer feedback and reflection to improve critical thinking and collaborative competencies.

The focus of the second cycle revolved around the utilisation of the colour sensor and the development of storytelling construction as problem-solving methodologies by building ‘Kiki’.

Although tablets were unavailable, learners organised into groups of three, and using the computer room, demonstrated remarkable skill in crafting clear problem statements. They actively identified multiple challenges, examining underlying factors and combining their observations into concise statements. Their analytical thinking abilities were showcased in their construction and coding of the robot ‘Kiki’ using the Spike Prime™ application.

Working in groups of three and using the computer room, learners demonstrated creativity and technical skills in crafting stories enriched by sounds and the colour sensor feature. They effectively combined auditory signals and sensor triggered events to enhance narrative progression, showcasing innovative thinking and relational abilities.

The strengths and challenges observed informed future planning of learning opportunities, emphasising the need for ample opportunities for collaborative learning and individualised support. Additionally, ensuring adequate access to functional equipment was a critical factor in the success of future learning opportunities.

5.3.3 Cycle 3: Prototyping and testing grabber designs

5.3.3.1 Planning for transformation

The third cycle focused on evaluating the operational efficiency of two different grabber designs. The learning opportunities included:

- Describing what a prototype is
- Describing why prototypes are needed
- Describing the benefits of having multiple prototypes
- Generating two prototypes of a claw
- Completing a rubric on the collaborative efforts of the team
- Reflecting on feedback from teammates

5.3.3.2 Acting to transform

The learners were grouped into teams of three to engage in practical tasks designed to apply each learning component effectively.

Describing what a prototype is

This lesson delved into the fundamental concept of a prototype within the realm of design and development. Learners had to create a clear and concise definition of a prototype through detailed discussions and illustrative examples. The exploration honed in on the essential attributes and objectives of prototypes, highlighting their role as preliminary models or iterations of a product or design. Learners applied analytical reasoning as they scrutinised the concept, underscoring the importance of prototypes in testing and evaluating ideas, concepts, or functionalities before committing to large scale production. Through collaborative discussions, learners laid the groundwork for subsequent conversations regarding the significance and practical applications of prototypes in the design process, demonstrating their engagement in analytical thinking, a characteristic of quadrant A in the HBDI® framework.

Why prototypes are needed

Learners delved into a comprehensive exploration of the indispensable role prototypes play in the design and development process. Engaging in critical analysis, they discerned the multifaceted benefits that prototypes offer. Through interactive discussions and practical examples, learners unravelled the intrinsic value of prototypes in identifying and addressing potential flaws or issues early in the design phase. They examined how prototypes serve as invaluable tools for mitigating risks, reducing costs and facilitating iterative refinement. By delving into real world case studies and scenarios, learners deepened their understanding of the pivotal role that prototypes play in fostering innovation, problem-solving and user-centric design, demonstrating their engagement in practical thinking aligned with quadrant B in the HBDI® framework.

Benefits of having multiple prototypes

Learners investigated the strategic advantages of generating multiple prototypes during the design process. Through hands-on activities and collaborative brainstorming sessions, learners explored the diverse benefits of experimenting with multiple design iterations. They examined how the iterative nature of prototyping enables them to explore different design concepts, functionalities and approaches. By engaging in iterative experimentation, learners developed a nuanced understanding of how multiple prototypes facilitate exploration, evaluation and optimisation of design solutions, embodying the principles of experimental thinking characteristic of quadrant D in the HBDI® framework.

Generating two prototypes of a claw

At this point of the learning opportunity, the focus shifted towards practical application as learners undertook the task of generating two distinct prototypes of a claw design. Through collaborative teamwork and creative ideation, learners translated conceptual ideas into tangible prototypes. They engaged in hands-on activities, including sketching, prototyping and testing, to bring their design concepts to life. By navigating through the intricacies of design implementation and iterative refinement, learners gained practical experience in prototype development. Through collaborative problem-solving and experimentation, learners honed their competencies in design thinking, innovation and creativity, demonstrating their engagement in relational thinking characteristic of quadrant C in the HBDI® framework.

Completing a rubric on the collaborative efforts of the team

Completing a rubric on the collaborative efforts of the team involved assessing and evaluating how well the team worked together towards a common goal. The rubric (found in Appendix A) outlined specific criteria or expectations for teamwork, such as communication, cooperation, leadership and contribution. Team members individually assessed their own and their teammates' performance based on these criteria, assigning scores or ratings to indicate the level of achievement (quadrant A). It was evident in the rubric completion, where learners analysed and evaluated their teamwork objectively. This process helped provide a structured evaluation of teamwork, highlighting areas of strength and areas needing improvement. It also encouraged team members to reflect on their own contributions and those of their peers, fostering accountability and a shared understanding of effective collaboration.

Reflecting on feedback from teammates

Reflecting on feedback from teammates involved considering the comments, suggestions and observations provided by other team members regarding one's own performance; required learners to engage in relational thinking (quadrant C). This reflection process allowed individuals to gain insights into how their actions and behaviours impacted the team dynamic and outcomes. It also provided an opportunity to consider different perspectives and identify areas for personal growth and development. By reflecting on feedback, individuals could learn from their experiences, improve their teamwork competencies and contribute more effectively to future team projects. The rubrics used to rate teammates could be found in Appendix A.

5.3.3.3 Observing the transformation

Observation for describing what a prototype is - outcome

During this step of the lesson, despite facing challenges related to the unavailability of tablets and limited robotic sets, learners demonstrated a clear understanding of what a prototype is, showcasing analytical thinking competencies aligned with quadrant A of the HBDI® framework. Through interactive discussions and visual aids, they articulated that a prototype serves as a preliminary version or model of a product or design. Learners accurately described prototypes as essential tools used to test and evaluate ideas, concepts or functionalities before committing to full scale production. Their ability to grasp the concept of a prototype indicated a solid foundation in the initial stages of the design process, reflecting their analytical thinking abilities.

Observation for why prototypes are needed - outcome

Throughout the lesson, learners engaged in insightful discussions regarding the importance of prototypes, despite challenges such as disruptions caused by conflicts between participants after breaks due to unfair play in a soccer game. They demonstrated practical thinking aligned with quadrant B of the HBDI® framework, recognising that prototypes play a crucial role in identifying and addressing potential flaws or issues early in the design and development process. Furthermore, learners acknowledged that prototypes facilitate iteration and improvement of the final product by allowing valuable feedback from users or stakeholders. Their understanding of the necessity of prototypes underscored their appreciation for systematic and iterative design methodologies, indicative of their practical thinking competencies.

Observation for benefits of having multiple prototypes - outcome

Learners actively participated in activities focused on building multiple prototypes of a claw design (as depicted in Photo evidence 13 and 14), despite challenges related to not having enough robotic sets. They demonstrated the experimental thinking characteristic of quadrant D within the HBDI® framework, showcasing an understanding of the benefits of having multiple prototypes. Despite facing challenges related to the building process and managing delicate components, learners engaged in hands-on prototyping activities, experiencing the iterative nature of design and the value of experimentation in refining and optimising designs. Their enthusiasm and creativity in generating multiple prototypes reflected a deep appreciation for the iterative design process, emphasising their experimental thinking competencies.

Photo evidence 13 and 14 were images of a mechanical assembly constructed from LEGO® pieces. There is a pressure sensor used as a button to control the movement of the grabbers. This can be seen at the bottom of the robot. This also served as the handle for the grabbers. The hub is attached to the handle and the motor to ensure connectivity between the button and the motor. The motor regulated the movement of the grabbers. When the designated button is pressed, the grabbers expand, making them open. On the other hand, when the button is released, the grabbers contract, causing them to close and allowing the apparatus to securely grasp and lift objects.

Photo evidence 15

Grabber prototype 1

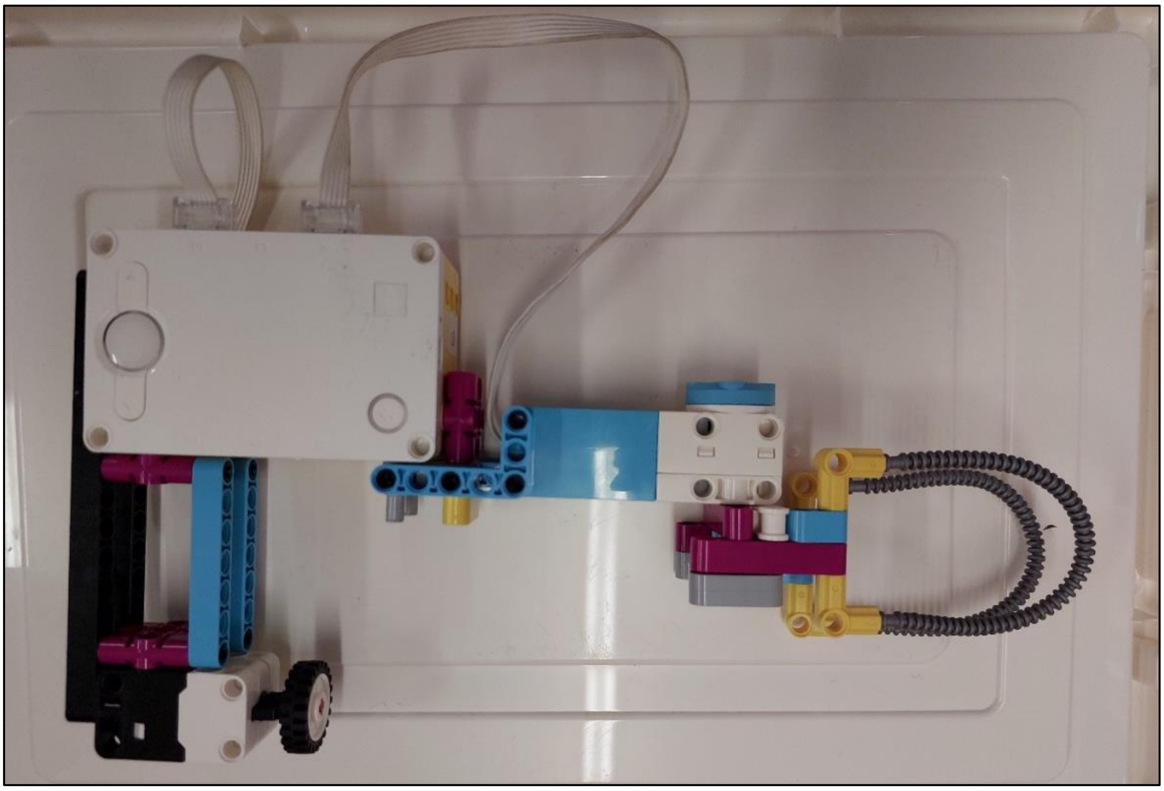
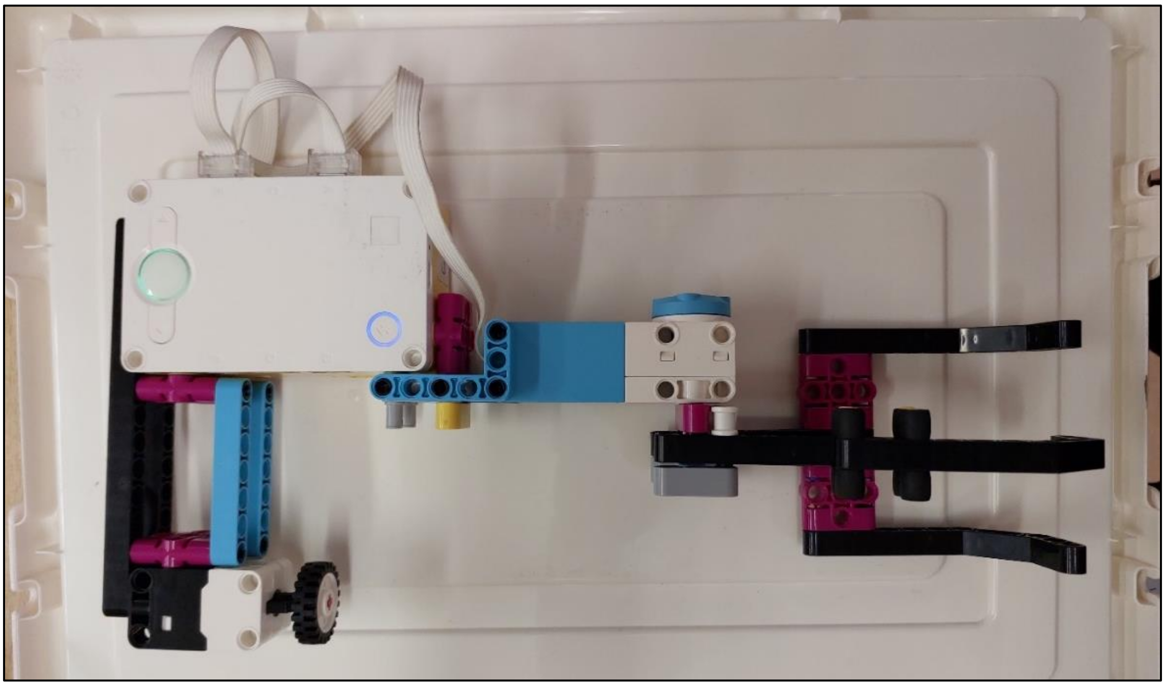


Photo evidence 16

Grabber prototype 2



Observation for generating two prototypes of a claw - outcome

During the practical section of the lesson, learners enthusiastically generated two prototypes of a claw design (as seen in Photo evidence 13 and 14), showcasing their relational thinking competencies aligned with quadrant C of the HBDI® framework. Despite challenges such as the need for colour coded building instructions to facilitate the building process, learners worked collaboratively in teams, leveraging their understanding of design principles to develop innovative solutions. Through brainstorming, sketching and prototyping, they explored different design concepts, materials and mechanisms for the claw. Their engagement in the prototyping process showcased their creativity, problem-solving competencies and ability to collaborate effectively with others, indicative of their relational thinking abilities.

Completing a rubric on the collaborative efforts of the team

During the observation of the activity involving the completion of a rubric on the collaborative efforts of the team, learners demonstrated a keen understanding of teamwork dynamics and a structured approach to evaluating their performance. The rubric, as outlined in Appendix A, provided clear criteria for assessing teamwork, including communication, cooperation, leadership and contribution. Learners engaged in analytical thinking (quadrant A) as they objectively analysed and evaluated their own and their teammates' performance based on these criteria. This structured evaluation process highlighted areas of strength and areas needing improvement, encouraging learners to reflect on their contributions and those of their peers.

Reflecting on feedback from teammates

Reflecting on feedback, learners engaged in relational thinking (quadrant C). Learners considered the comments, suggestions and observations provided by their teammates regarding their performance. This reflection process allowed individuals to gain insights into how their actions and behaviours impacted the team dynamic and outcomes. It also provided an opportunity for learners to consider different perspectives and identify areas for personal growth and development.

5.3.3.4 Reflecting on transformation

This stage of the action research aimed to enhance the learners' prototyping abilities by utilising the Spike Prime™ platform. Despite ongoing difficulties with equipment availability, the learners' enthusiasm and engagement remained praiseworthy. The learning opportunities emphasised the significance of presenting explicit visual aids and building instructions to facilitate the construction process. Furthermore, they emphasised the necessity of actively managing group dynamics to guarantee a learning atmosphere conducive to effective knowledge creation.

The identified strengths and challenges from cycle 2 persistently guided the development of the plans for learning opportunities. Techniques for handling conflicts and promoting favourable group interactions were incorporated to improve the overall educational encounter. I solicited feedback from learners regarding their group experiences, as delineated in Appendix A. Subsequently, learners were required to engage in reflection concerning methods to enhance their teamwork and collaboration competencies.

In the future, it would be advantageous to investigate alternative approaches for distributing equipment and to incorporate supplementary visual tools to enhance the learners' prototyping efforts.

5.3.4 Cycle 4: Evaluating grabber efficiency and product reviews

5.3.4.1 Planning for transformation

The fourth cycle continued the evaluation of grabber efficiency, emphasising the criteria for informed product reviews. The learning opportunities are as follows:

- Choosing the best prototype
- Justifying the choice with motivation

5.3.4.2 Acting to transform

Learners collaborated in pairs, ensuring focused attention. This step demonstrated ongoing learner engagement and effective communication (quadrant A, B and D) in articulating justifications for their choices.

Choosing the best prototype and justifying the choice

In the final section of the lesson, learners were tasked with engaging in critical evaluation and decision making to determine the most optimal prototype from the grabbers made in the previous lesson. They drew upon predefined criteria such as picking up a bottle, LEGO® block, scrunched up paper, a LEGO® wheel and an apple. Through deliberative discussions and evidence-based justifications, learners justified the selection of the superior design iteration. By demonstrating a mature understanding of design evaluation principles and iterative refinement processes, learners showcased their analytical thinking competencies and ability to make informed design decisions, reflecting their engagement in analytical thinking (quadrant A) as well as practical thinking (quadrant B) in the HBDI® framework.

5.3.4.3 Observing the transformation

Observation for choosing the best prototype and justifying the choice outcome

Following the generation of multiple prototypes, learners engaged in critical evaluation to choose the best prototype for further development. The worksheets with criteria can be seen in Appendix B. This demonstrates a blend of analytical (quadrant A) and practical (quadrant B) thinking competencies. Despite facing challenges related to task division and managing cables, they carefully assessed each prototype based on predefined criteria such as functionality, ease of use and effectiveness.

Through thoughtful deliberation and discussion, learners justified their choice of the best prototype, articulating specific reasons and considerations that informed their decision-making process. Their ability to critically evaluate prototypes and make informed decisions underscored their analytical thinking competencies and demonstrated a mature understanding of design evaluation principles, reflecting their practical thinking abilities as well.

Challenges related to equipment availability and time constraints persisted. Some learners left early due to extracurricular activities, impacting their ability to fully engage in the testing process. Additionally, I continued to face challenges with limited access to tablets for coding purposes.

For learners, challenges included the need for consistent testing conditions and the importance of precise measurements. Some groups encountered difficulties in maintaining controlled experiments, highlighting the need for additional guidance in this area.

Strengths remained centred around active participation and engagement (quadrant C) in the evaluative process. Learners excelled in analysing and comparing the performance of the grabber designs, showcasing their ability to think critically.

5.3.4.4 Reflecting on transformation

This stage of the action research initiative highlighted the significance of practical experimentation and rigorous assessment opportunities in the design process. Despite ongoing difficulties regarding equipment availability and time limitations, the learners' enthusiasm and active participation remained praiseworthy. Some groups demonstrated adaptive behaviour in response to conflicts encountered in the previous cycle by breaking down the building steps and dividing them among themselves. This approach aimed to distribute the workload more evenly and promote a more collaborative and harmonious working environment within the groups.

After careful consideration, it became clear that the design of future learning opportunities should be heavily influenced by a comprehensive understanding of the strengths and challenges encountered during the educational process. This involves a thorough examination of the learners' reactions, levels of involvement and educational achievements. An essential lesson from this evaluation is the significance of consistently prioritising practical and experiential learning approaches. These approaches not only encourage active involvement and participation but also act as catalysts for developing the analytical and communicative competencies of the learners.

5.3.5 Cycle 5: Evaluating grabber efficiency and product reviews continued

5.3.5.1 Planning for transformation

The initial step of the action research initiative centred on evaluating the efficacy of two distinct grabber designs based on learners' observations, test dimensions, and load bearing capacity. This section included a deliberative discussion on the criteria for determining the superior design and the methodology for product assessment. The learning opportunities are as follow:

- Describing which product works best
- Motivating why they think a specific product works best
- Making recommendations based on observations
- Creating a product review

5.3.5.2 Acting to transform

Describing which product works best

Learners engaged in analytical thinking (quadrant A) as they articulated the key features and functionalities of each grabber built with the LEGO® Spike Prime™ set. Through detailed descriptions, learners identified the design elements, mechanisms and intended purposes of each grabber, fostering a systematic approach to problem-solving and analysis.

Motivating why they think a specific product works best

Learners applied practical thinking (quadrant B) as they provided reasoning and justification for their choice of the grabber they believed worked best for a given task or scenario. This involved critically assessing the effectiveness, efficiency and suitability of each grabber based on their observations and understanding of their capabilities, promoting the application of technical knowledge to real world situations.

Making recommendations based on observations

Learners integrated relational thinking (quadrant C) as they drew conclusions and made recommendations based on their evaluations of the two grabbers. Recommendations were informed by factors such as functionality, ease of use, durability and adaptability, emphasising the importance of interpersonal relationships and effective communication in collaborative decision-making processes.

Creating a product review

Learners embodied experimental thinking (quadrant D) as they synthesised their findings into a comprehensive product review, documenting their assessments, recommendations, and overall impressions of each grabber. This review served as a structured evaluation of the grabbers, encouraging exploration, innovation and creativity in the evaluation and refinement of design solutions.

5.3.5.3 Observing the transformation

Observation for "learners can describe which product works best" outcome

Throughout this learning opportunity, learners demonstrated their capability to discern and articulate which of the two grabber designs they deemed most effective. Employing analytical thinking (quadrant A), they meticulously analysed the features, mechanisms and functionalities of each grabber, considering factors such as grip strength, flexibility and ease of use. Through detailed descriptions and comparisons, learners showcased their understanding of the strengths and limitations of each design, providing a rationale for their selection of the preferred grabber. Their ability to describe and evaluate the performance of each product reflected a solid grasp of analytical thinking competencies, underlining their capacity to assess and make informed decisions based on evidence and observations.

Observation for "motivate why they think a specific product works best" outcome

During this segment of the lesson, learners adeptly justified why they believed a specific grabber design outperformed the other. Applying practical thinking competencies (quadrant B), they presented compelling justifications and reasoning to support their choice of the preferred grabber. Drawing upon their observations and assessments, learners articulated how particular design features or functionalities contributed to the effectiveness and efficiency of the chosen grabber in fulfilling assigned tasks. Through persuasive arguments and evidence-based explanations, learners showcased their ability to apply technical knowledge and critical thinking to real world scenarios, emphasising the practical relevance of their decision-making process.

Observation for "make recommendations based on observations" outcome

Amidst collaborative discussions, learners formulated recommendations grounded in their observations of the two grabber designs. Leveraging relational thinking competencies (quadrant C), they considered various factors such as functionality, usability, durability and adaptability to offer well informed recommendations. Through constructive dialogue and consensus building, learners pinpointed areas for improvement and suggested modifications or enhancements to optimise the performance of the grabbers. Their ability to collaborate effectively and communicate their recommendations reflected a mature understanding of relational dynamics and the significance of interpersonal relationships in collaborative decision-making processes.

Observation for "create a product review" outcome

As the lesson reached its conclusion, learners synthesised their evaluations and recommendations into comprehensive product reviews. Embracing experimental thinking (quadrant D), they documented their assessments, insights and overall impressions of each grabber design in a structured format. Through written or verbal reflections, learners provided detailed analyses of the grabbers' strengths, weaknesses and potential areas for refinement. Their product reviews served as valuable documentation of the iterative design process, fostering a culture of exploration, innovation and continuous improvement. By engaging in reflective practice and sharing their perspectives, learners demonstrated their ability to critically evaluate design solutions and contribute to the iterative refinement of products and prototypes.

5.3.5.4 Reflecting on transformation

The initial step of the action research initiative focused on the thorough assessment and comparative examination of two different grabber designs using the Super Cleanup Claw Spike Prime™ set. The learning objectives (learning opportunities) aimed at enhancing learners' analytical, practical, relational and experimental thinking competencies through structured assessment and evaluation activities.

Despite overall success, several challenges arose during this cycle. These challenges included reliance on technology, maintaining a consistent curriculum and ensuring the involvement of all learners, especially those who left early in the previous cycle (cycle 4) to attend a sports event.

One major challenge was the reliance on personal computing resources for coding, highlighting the need for alternative coding platforms or the provision of loaner devices to alleviate this bottleneck. Another challenge was the assumption that learners remember previous material well, indicating the importance of reviewing and clarifying previous concepts at the beginning of each learning opportunity. Additionally, the premature departure of certain learners for a swimming gala underscored the need for carefully planned timetabling to accommodate extracurricular obligations and minimise interruptions to the learning process.

Moving forward, the knowledge acquired from this cycle will serve as a guiding principle for future planning and implementation. By anticipating potential challenges, implementing detailed planning and maintaining effective communication, I can ensure fair availability of educational resources and maximise learner participation. Continuous reflection and adaptation of the educational methodology will be crucial for improving planning for learning opportunities and delivery thereof, ensuring that all learners have equal opportunities to achieve the intended learning outcomes.

5.3.6 Cycle 6: Enhancing design and functionality

5.3.6.1 Planning for transformation

In this step, the focus shifted towards building a robot without knowing what the purpose of it was. Learners needed to determine the intended functionality of this robot.

Photo evidence 17 and 18 are images of a mechanical assembly constructed from LEGO®. The assembly includes gears and levers, indicative of a simple machine. The base of the structure is made of yellow plastic blocks. A blue rectangular frame, possibly representing a screen or window, is attached to the base. There is a black lever or arm connected to a purple and black gear mechanism at the base. Various colourful blocks are scattered around, including blue flat pieces on the yellow base. The hub is attached to the back to make the gears move. This "thing" uses a motor to rotate something from one side to the other.

Photo evidence 17

"New thing" side 1

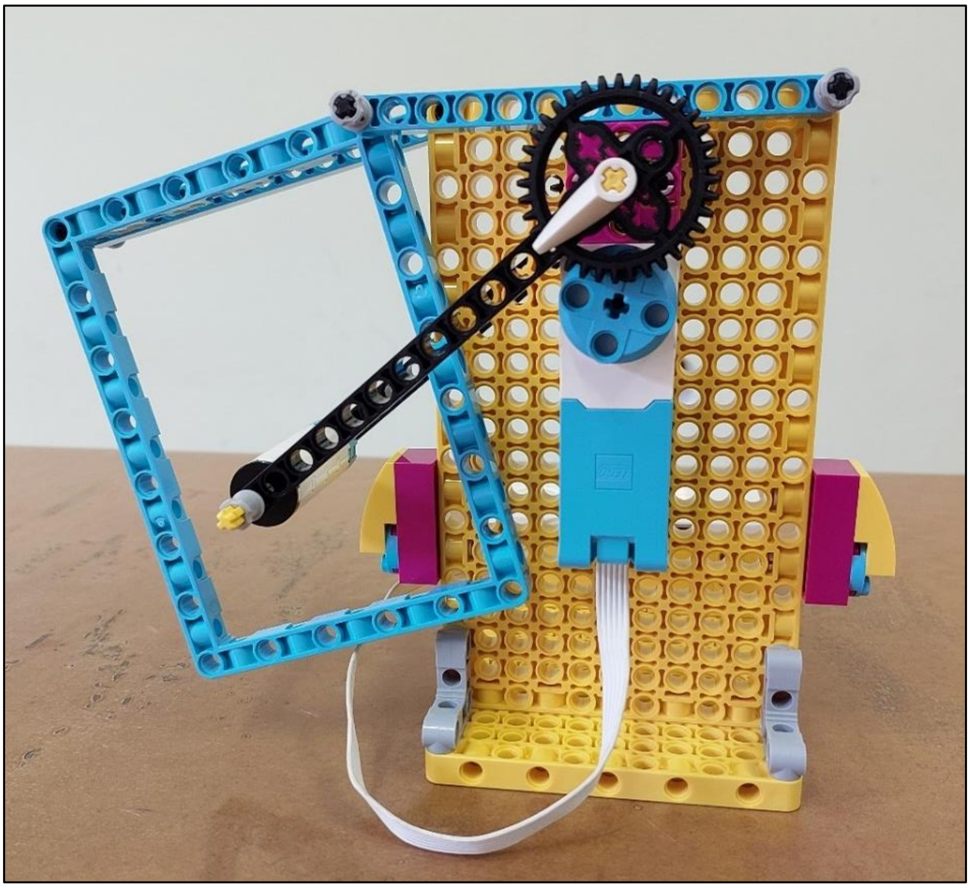
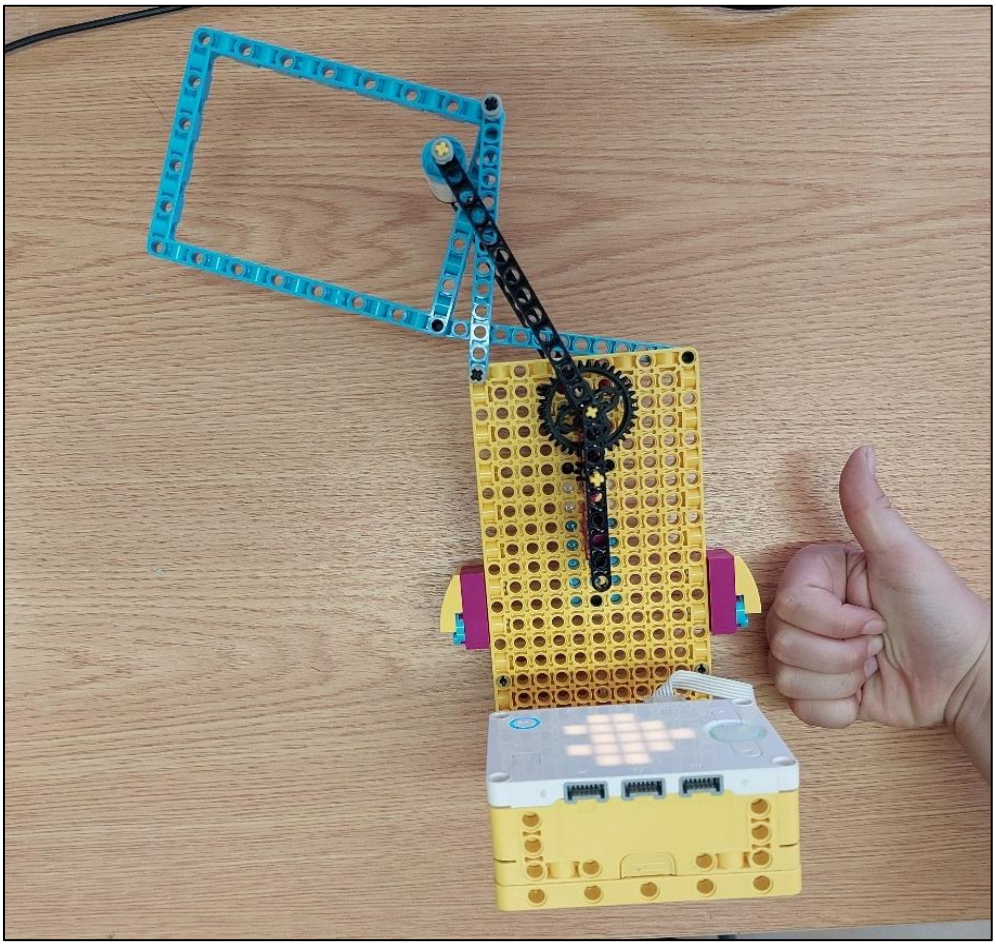


Photo evidence 18

"New thing" side 2



The learning opportunities include:

- Defining the term “argument”
- Forming an argument
- Defining, customising and communicating the use of the “new thing”

5.3.6.2 Acting to transform:

Defining the term "argument"

This objective primarily engaged learners in analytical thinking (quadrant A) as they deconstructed the concept of an argument and analysed its components. They used logical analysis and critical reasoning to understand the purpose and structure of arguments.

Forming an argument

The process of forming an argument involved practical thinking (quadrant B) as learners applied their technical knowledge to construct persuasive arguments. They engaged in hands-on activities and guided practice to develop the competencies necessary for crafting coherent and well supported arguments.

Defining, customising and communicating the use of the "new thing" Introducing and integrating a new concept into their arguments required relational thinking (quadrant C). Learners effectively communicated and engaged in interpersonal relationships as they adapted and customised the new information to enhance the depth and persuasiveness of their arguments.

5.3.6.3 Observing the transformation

Defining the term "argument"

Throughout this stage of the lesson, learners exhibited a distinct comprehension of the notion of an argument. By engaging in interactive discussions, they successfully decided on the elements of an argument, such as its purpose, structure and techniques for persuasive communication. By participating in analytical thinking (quadrant A), learners demonstrated their ability to engage in logical analysis and employ critical reasoning competencies while examining different examples of arguments. Their proficiency in defining and expressing the term "argument" demonstrated a thorough understanding of fundamental principles in persuasive communication, establishing a firm basis for future learning.

Forming an argument

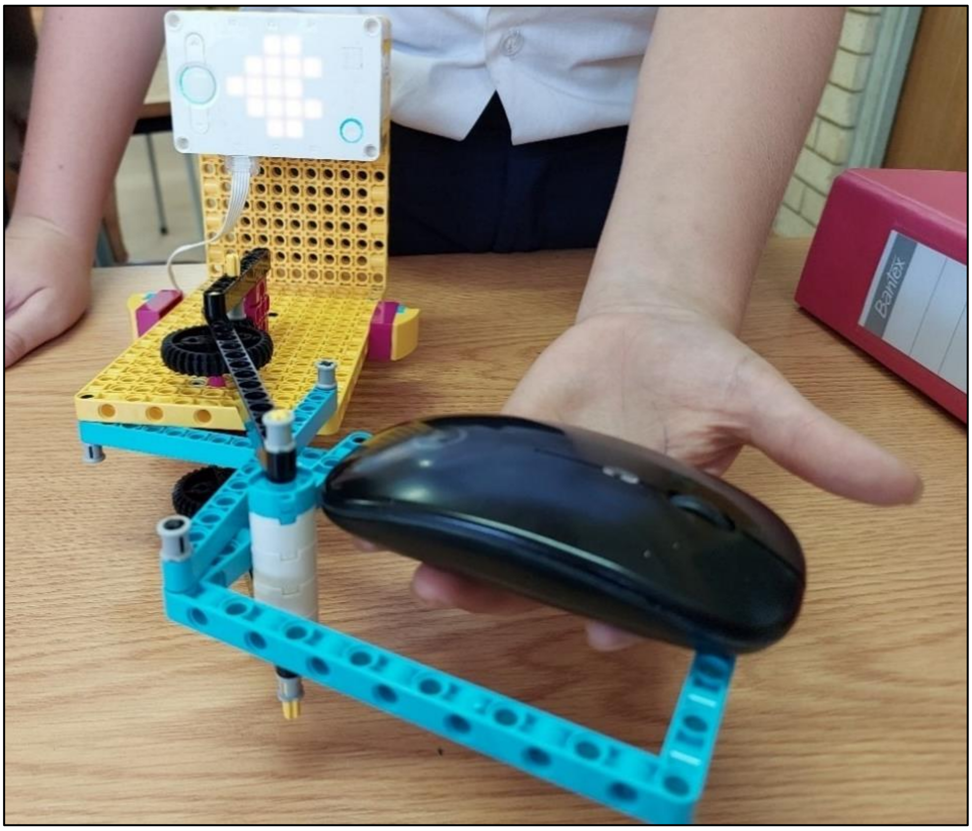
During this portion of the lesson, learners actively utilised their comprehension of argumentative principles to formulate compelling arguments. By employing practical reasoning (quadrant B), they applied their expertise and analytical abilities to develop logical and well substantiated arguments. Learners showcased their ability to create persuasive statements and address potential counterarguments through active participation in practical exercises and guided instruction. Their aptitude for constructing persuasive arguments demonstrated their proficiency in logical reasoning and proficient communication, underscoring their development in persuasive discourse abilities.

Defining, customising and communicating the use of the "new thing"
During this stage of the lesson, learners were presented with the "new thing". Several challenges were encountered during this learning opportunity. Notably, a significant number of learners were absent, affecting group dynamics. Additionally, there were technical hurdles as some new tablets struggled to load the learning opportunities objectives due to prior connectivity issues arising from power outages. For some learners, the process of redesigning the “new thing” proved to be emotionally taxing. One group in particular, exhibited a high degree of reliance on affirmations and reassurance, particularly the designated group leader. This learner grappled with self-doubt, frequently seeking validation, which may have stemmed from a lack of confidence in their building abilities. Furthermore, some learners faced difficulties in basic problem-solving, occasionally making errors that necessitated backtrack solutions.

Nonetheless, by employing relational thinking (quadrant C), learners successfully tailored and conveyed the utilisation of the "new thing" through interactive discussions and collaborative activities, within the framework of their arguments. As illustrated in Photo evidence 19, one group built a robot that could move a mouse when not at a desk. Another group (as illustrated in photo evidence 19) believed this robot could be used to pass on a hand towel after washing hands. Their aptitude for assimilating innovative concepts and viewpoints demonstrated their receptiveness to fresh educational encounters and their proficiency in innovative troubleshooting. In general, learners exhibited a comprehensive approach to argumentation, incorporating both conventional and inventive techniques to formulate persuasive and compelling arguments.

Photo evidence 19

"New thing" mouse mover



5.3.6.4 Reflecting on transformation

This step of the action research initiative was dedicated to refining and enhancing the "new thing" using the Spike Prime™ platform. Despite notable successes, several challenges emerged, impacting the overall dynamics of the session.

The absence of a considerable number of learners presented an unforeseen challenge, influencing group dynamics and potentially hampering collaborative efforts. Moreover, technical impediments arose as new tablets encountered difficulties in loading the prescribed learning opportunities objectives due to prior connectivity issues. This highlighted the importance of robust technological support to ensure seamless educational delivery.

The emotional aspect of learning also came to the fore during this learning opportunity. One group demonstrated a pronounced need for affirmation and reassurance, particularly the designated group leader (appointed during the previous cycle). This serves as a poignant reminder of the importance of fostering a supportive and encouraging learning environment, particularly in endeavours that demand creative problem-solving and hands-on construction.

Furthermore, some learners grappled with the intricacies of basic problem-solving, encountering occasional setbacks that required them to backtrack and re-evaluate their approach. This process underscores the iterative nature of design thinking and the critical role of resilience in the face of challenges.

The small group size emerged as a notable strength, fostering intimate collaboration and affording each learner ample opportunities for hands-on engagement. This facilitated deeper exploration of design constructs and greater individual involvement in the refinement process.

5.3.7 Cycle 7: Navigating Spike Prime™ application on the Samsung Galaxy Tab A7 Lite

5.3.7.1 Planning for transformation

The purpose of this action research cycle was to enhance learners' proficiency in using the LEGO® Spike Prime™ application. The learning opportunities are as follow:

- Navigate to the LEGO® Spike Prime™ application on the tablet
- Creating and name folders to save their progress in
- Taking screenshots of their code and pictures of their robots
- Connecting the Hub to their tablets
- Managing their projects on the LEGO® Spike Prime™ applications
- Defining the code blocks
- Downloading and running programmes created by learners from the tablet to the hub

5.3.7.2 Acting to transform

The learning opportunities strategy employed pair work and collaborative endeavours among pairs to promote inquiry-based learning. Participants collaborated in pairs, actively interacting with the application to accomplish the following objectives:

Navigating to the Spike Prime™ application on the tablet

Throughout this action research cycle, learners were presented with the challenge of accessing the LEGO® Spike Prime™ application on the tablet. Engaging in experiential learning (quadrant D), learners embarked on a journey to acquire proficiency in navigating the application's user interface through a series of interactive demonstrations and challenges. By immersing themselves in hands-on activities and guided learning opportunities, learners actively explored the features and functionalities of the application, enabling them to efficiently access the essential tools and resources necessary for their projects. This process facilitated relational thinking (quadrant C) as learners integrated their understanding of the application's interface with their project objectives, enhancing their ability to leverage technology for educational purposes. Additionally, through iterative experimentation and problem-solving, learners cultivated an experimental mindset, fostering adaptability and innovation in their approach to utilising digital tools for learning. Overall, this experience empowered learners to navigate the Spike Prime™ application confidently, equipping them with valuable digital literacy competencies essential for success in today's technologically driven world.

Creating and naming folders in which to save progress

Learners were tasked with unravelling the process of creating and labelling folders within the LEGO® Spike Prime™ application; a task essential for efficiently categorising and storing their work. Through experiential learning (quadrant D), learners actively engaged in practical exercises aimed at acquiring the proficiency needed to effectively handle their files. By immersing themselves in hands-on activities and guided learning opportunities, learners gained a thorough understanding of the folder creation and labelling process, ensuring that their projects were meticulously organised and readily accessible for future reference. This process fostered analytical thinking (quadrant A) as learners systematically approached the organisation of their files, considering factors such as project relevance and accessibility. Additionally, through iterative practice and reflection, learners honed their competencies in file management, cultivating an experimental mindset (quadrant D) that encouraged adaptability and innovation in their approach to organising digital resources. Overall, this experience empowered learners with the knowledge and competencies necessary to efficiently navigate and manage their files within the Spike Prime™ application, facilitating seamless project management and enhancing productivity in their learning endeavours.

Taking screenshots of code and pictures of robots

During this stage of the lesson, learners were challenged with acquiring the skill of capturing screenshots of their code and pictures of their robots using the tablet's camera. Through experiential learning (quadrant D), learners actively engaged in hands-on challenges aimed at familiarising themselves with the tablet's camera functionalities and the process of capturing screenshots. By navigating through the tablet's interface and experimenting with different features, learners gained proficiency in the task of documenting their work. This process fostered practical thinking (quadrant B) as learners applied their technical knowledge and problem-solving competencies to identify the appropriate buttons or commands for capturing screenshots. Additionally, collaboration with peers and seeking guidance from peers, demonstrated relational thinking (quadrant C) as they communicated and shared their findings and insights regarding the screenshot capture process. Through iterative practice and feedback, learners refined their competencies in documentation, enhancing their ability to communicate and collaborate effectively with both peers and instructors. Overall, this experience empowered learners with the essential skill of capturing screenshots, facilitating clear communication and efficient collaboration in their learning journey.

Connecting the hub to their tablets

At this point of the learning opportunity, learners were guided on how to establish a Bluetooth connection between the Hub and their tablets, facilitating seamless communication and data transfer between the two devices. Through systematic learning opportunities and hands-on practice, learners developed proficiency in configuring Bluetooth settings on both the Hub and their tablets. This process involved practical thinking (quadrant B) as learners applied technical knowledge to navigate the Bluetooth settings and initiate the pairing process. Additionally, learners engaged in analytical thinking (quadrant A) as they identified and resolved potential connectivity issues, such as signal interference or device compatibility issues. By actively participating in the Bluetooth setup process, learners fostered experiential learning (quadrant D), gaining practical experience in establishing wireless connections for their robotics projects. Furthermore, through collaborative efforts and peer support, learners demonstrated relational thinking (quadrant C) as they shared insights and troubleshooting strategies to ensure successful Bluetooth pairing. Overall, this guided activity equipped learners with the necessary competencies to establish reliable Bluetooth connections, enabling efficient communication and data exchange between the Hub and their tablets for their robotics endeavours.

Managing projects on the LEGO® Spike Prime™ applications

During this stage of the lesson, learners took the initiative to explore the project management features available within the LEGO® Spike Prime™ application. Through guided facilitation and collaborative discussions, learners actively engaged with the application interface to understand its functionalities and capabilities. By working together in small groups, learners shared ideas and insights, collectively discovering how to create, modify and organise projects effectively. This learner-centred approach encouraged autonomy and independent exploration, allowing each learner to navigate the application at their own pace and according to their individual learning preferences. As they interacted with the Spike Prime™ application, learners had to apply their technical knowledge and problem-solving competencies to overcome challenges and optimise their project management workflows. Through this interactive and self-directed learning experience, learners not only gained proficiency in using the LEGO® Spike Prime™ application, but also developed critical thinking and teamwork competencies essential for real world applications.

Using code blocks

Participants took an active role in exploring and understanding the various code blocks available in the LEGO® Spike Prime™ application. Through guided exploration and hands-on experimentation, learners delved into the functionalities of each code block, gaining a comprehensive understanding of their capabilities and potential applications. This process fostered analytical thinking (quadrant A) as participants logically analysed the functions and interactions of different code blocks. Additionally, the practical application of these blocks encouraged experimental thinking (quadrant D), as participants creatively experimented with different combinations to achieve desired outcomes. By immersing themselves in the learning process, participants engaged in holistic learning experiences that catered to diverse cognitive preferences and promoted deeper comprehension of coding concepts. As a result, participants were equipped with the knowledge and competencies needed to develop innovative and customised programs tailored to their specific robotics projects.

Downloading and running programs from the tablet and the hub

Learners were actively engaged in acquiring the necessary knowledge and competencies to download and execute programs from both the tablet and the hub at this point of the learning opportunity. Through hands-on demonstrations and guided exercises, participants took ownership of their learning journey, immersing themselves in practical activities to transfer programs seamlessly between devices. By navigating the interface of the LEGO® Spike Prime™ application and troubleshooting any challenges encountered, learners empowered themselves to integrate hardware and software components effectively. This learner centred approach fostered a sense of autonomy and confidence, enabling participants to take charge of their robotics projects and drive their own learning experiences. This activity primarily engaged learners in practical thinking (quadrant B) as they applied technical knowledge to execute programs and troubleshoot any issues encountered. Additionally, it fostered relational thinking (quadrant C) as learners collaborated with peers and instructors to navigate the LEGO® Spike Prime™ application interface and integrate hardware and software components effectively.

5.3.7.3 Observing the transformation

Navigating to the LEGO® Spike Prime™ application on the tablet

During the observation, learners demonstrated varying levels of familiarity with navigating to the LEGO® Spike Prime™ application on their tablets. While some learners quickly learnt to locate the application icon and opened it without hesitation, others required additional time and guidance. I motivated learners to seek guidance from their peers. This activity primarily engaged learners in practical thinking (quadrant B) as they engaged in hands-on navigation tasks and benefited from sequential learning opportunities. Overall, most learners successfully navigated to the LEGO® Spike Prime™ application, albeit with varying degrees of efficiency. Photo evidence 20 illustrates one pair working together to navigate to the LEGO® Spike Prime™ application.

Photo evidence 20

Learners exploring the LEGO® Spike Prime™ application

Creating and naming folders in which to save their progress

At this point of the learning opportunity, learners actively participated in the creation and naming of folders within the Spike Prime™ application, aiming to organise their projects effectively. Some learners demonstrated proficiency by efficiently creating and labelling folders, while others took more time to deliberate on suitable names. Learners who favoured analytical thinking (quadrant A) spent more time deliberating on the most effective folder names, while those with a preference for practical thinking (quadrant B) focused on organising their folders efficiently. The class had a discussion on effective folder organisation strategies, encouraging learners to use descriptive names for better project management. This activity primarily engaged learners in practical thinking (quadrant B) as they navigated the application's interface and made decisions about folder structure and nomenclature. Despite some initial hesitation, all learners successfully completed the task, demonstrating their ability to organise and save their progress within the application.

Taking screenshots of their code and pictures of their robots

During the observation, learners demonstrated a proactive approach in utilising the tablet's camera function to capture screenshots of their code and images of their robots. Their engagement was marked by a palpable sense of enthusiasm, indicating their recognition of the significance of documenting their work thoroughly. Many learners exhibited a meticulous attitude by taking multiple screenshots to ensure comprehensive documentation. However, some learners encountered challenges in capturing clear images initially, prompting me to provide guidance and support. This activity predominantly fostered practical thinking (quadrant B) as learners applied technical competencies to capture and document their work effectively. Moreover, the emphasis on accurate documentation underscored the importance of organisational competencies and attention to detail, aligning with analytical thinking (quadrant A) in ensuring thorough and precise record keeping for future reference and troubleshooting purposes. Learners who leaned toward relational thinking (quadrant C) focused on capturing images that effectively conveyed their project progress, while those with a preference for experimental thinking (quadrant D) enjoyed exploring different camera angles and techniques for capturing images.

Connecting the hub to their tablets

Observations during the lesson revealed that learners demonstrated varying degrees of success in connecting the hub to their tablets via Bluetooth. While some learners adeptly established connections without difficulty, navigating the pairing process with confidence, others encountered challenges with connectivity, experiencing issues such as signal interference or device recognition errors. I played a crucial role in providing troubleshooting assistance to learners facing difficulties, asking questions to lead learners step-by-step to overcome common connectivity issues. Through patient guidance and support, I facilitated successful connections for all participants, ensuring that each learner could effectively interface their tablet with the Hub for seamless communication and data transfer.

This point of the lesson provided an opportunity for learners to engage in practical problem-solving (quadrant B), with those exhibiting a preference for analytical thinking focusing on troubleshooting connectivity issues by systematically identifying and addressing potential obstacles. Learners with a preference for experimental thinking (quadrant D) explored alternative approaches and techniques for establishing connections, demonstrating adaptability and a willingness to explore different strategies. Furthermore, learners who leaned towards practical thinking (quadrant B), demonstrated a purposeful approach to overcoming connectivity challenges, applying structured methods and logical reasoning to navigate the pairing process efficiently. Overall, the successful establishment of connections between tablets and the hub not only facilitated technical proficiency but also nurtured essential cognitive competencies, including analytical reasoning, adaptability and strategic problem-solving. Learners who favoured practical thinking (quadrant B), appreciated the troubleshooting guidance provided by me, while those with a preference for experimental thinking (quadrant B), enjoyed exploring alternative methods for establishing connections.

Managing their projects on the Spike Prime™ applications

Observations indicated that learners engaged in managing their projects within the LEGO® Spike Prime™ application interface. There was a diversity of project management strategies observed, with some learners organising projects meticulously while others adopted a more informal approach. I encouraged learners to maintain clear organisation and provided guidance on effective project management practices. Learners demonstrated growing proficiency in managing their projects, with many expressing appreciations for the organisational tools provided by the application.

In terms of HBDI® quadrants, learners who favoured practical thinking (quadrant B) tended to adopt structured workflows and meticulous organisation, utilising folders, tags and detailed file names to maintain clarity and structure in their projects. On the other hand, learners inclined towards relational thinking (quadrant C) prioritised collaboration and communication in project management, seeking input from peers and instructors to refine their organisational strategies. Meanwhile, learners with a preference for experimental thinking (quadrant D) approached project management with creativity and adaptability, exploring different methods and tools to find the most effective organisational approach. Finally, learners with a focus on analytical thinking (quadrant A) applied logical reasoning and systematic planning to their project management strategies, ensuring that tasks were executed efficiently, and goals were achieved effectively.

Defining the code blocks

Throughout the observation, learners actively participated in discussions and exercises aimed at defining various code blocks within the Spike Prime™ application. I facilitated collaborative exploration, encouraging learners to analyse and articulate the functions of different code blocks. Learners demonstrated growing proficiency in understanding and defining code blocks, with many expressing confidence in their abilities by the end of the section. I emphasised the importance of clear communication and documentation when working with code blocks to ensure accuracy and efficiency in programming.

In terms of HBDI® quadrants, learners who favoured analytical thinking (quadrant A) excelled in dissecting the functions of code blocks, breaking down complex concepts into manageable components and logically analysing their functionalities. They approached the task with a methodical and systematic mindset, focusing on understanding the underlying principles behind each code block. On the other hand, learners with a preference for practical thinking (quadrant B) focused on applying the code blocks to real world scenarios, seeking practical applications for the concepts they learnt. They prioritised hands-on experimentation and problem-solving, aiming to utilise code blocks effectively in robotics projects.

Downloading and running programs created by learners from the tablet to the hub

At this point of the learning opportunity, learners embarked on the task of downloading and running programs created by themselves or their peers from the tablet to the hub. While some learners navigated this process smoothly, others encountered initial challenges, particularly regarding device compatibility and downloading procedures. I intervened by troubleshooting technical issues as they arose. Through collaborative efforts and guidance, all learners successfully downloaded and executed programs on the hub.

In terms of quadrants, learners who leaned toward analytical thinking (quadrant A) focused on understanding the technical aspects of the downloading process, analysing the steps involved, and ensuring compatibility between devices. They approached the task with a logical and detail-oriented mindset, seeking to comprehend the underlying mechanisms of the downloading procedure. Conversely, learners with a preference for practical thinking (quadrant B) prioritised hands-on experimentation and problem-solving, actively engaging in the downloading process and troubleshooting any encountered issues. They emphasised the practical application of programming competencies and the importance of effectively executing programs on the hub to achieve desired outcomes.

Overall observations

The observations underscored learners' active engagement and advancements in navigating the LEGO® Spike Prime™ application, organising their projects and employing essential functionalities to document their work proficiently. Despite occasional hurdles, such as limited independent exploration tendencies among learners and unexpected challenges like high school learners' Wi Fi usage affecting network bandwidth, participants demonstrated resilience and a collaborative spirit. It's worth noting that the recent acquisition of tablets prompted the delay in the exploration of tablet related lessons, explaining why this session focused solely on familiarising learners with the tablet's functionalities. Nonetheless, the session provided valuable opportunities for skill development and collaborative learning, contributing to learners' growth and proficiency in robotics programming.

5.3.7.4 Reflecting on transformation

The seventh cycle of the action research initiative focused on developing expertise in effectively navigating and utilising the Spike Prime™ application. Despite achieving some level of success, various challenges emerged, prompting a thorough examination of the pedagogical approach. One challenge was learners' reluctance to engage in independent exploration, preferring activities guided by an instructor. This highlighted the need to provide support and structure for independent exploration while balancing guidance and autonomy.

Additionally, unexpected technical limitations, such as Wi Fi issues, underscored the importance of thorough contingency planning and possible adjustments in case of unforeseen interruptions. These challenges emphasised the need to implement strategic actions to address and minimise potential technical limitations, ensuring a smooth and uninterrupted delivery of learning opportunities. One of these interruptions included other learners gaining access to the Wi Fi, impacting network bandwidth and causing disruptions.

The knowledge acquired from this cycle serves as a pivotal point for future planning and implementation. Moving forward, it was crucial to strike a balance between providing structured guidance and allowing for independent exploration to maximise the learning experience. By implementing these insights, I aimed to enhance the effectiveness of future learning opportunities, ensuring that learners had the support and resources necessary to succeed in navigating and utilising educational technologies like the Spike Prime™ application.

5.3.8 Cycle 8: Exploring advanced coding constructs

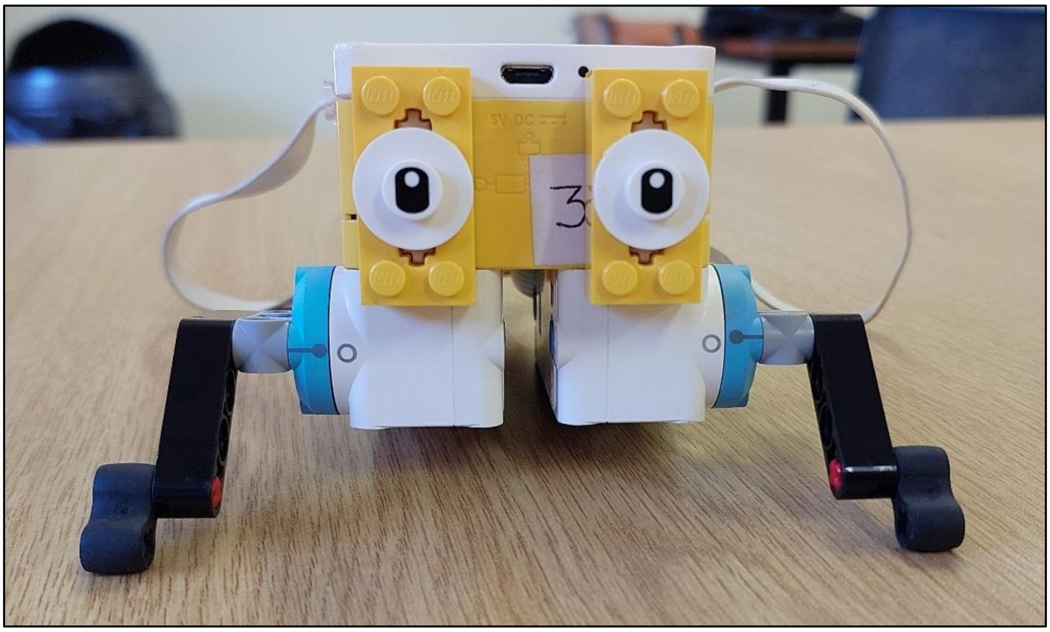
5.3.8.1 Planning for transformation

The eighth iteration of the action research initiative focused on advancing learners' coding competencies by exploring complex constructs. The central objective was to equip the ‘Hopper’, with intricate movement sequences. In the LEGO® Spike Prime™ application, the ‘Hopper’ refers to a specific robotic model or design that can be built using the Spike Prime™ set. The Hopper typically consists of components such as the hub, motors and various LEGO® pieces assembled in a specific configuration to create a functional robot. This robot uses legs to move, not wheels. An illustrative example of the Hopper, comprising the hub, two motors and assorted LEGO® pieces, is depicted in Photo evidence 21. Throughout the lesson, the following were targeted:

- Transforming the Hopper into a functional driving base
- Creating a programming code that enables the Hopper to move forward, in a straight line
- Creating a programming code that enables the Hopper to move backwards and make turns

Photo evidence 21

Built Hopper



5.3.8.2 Acting to transform

Transforming the Hopper into a functional driving base

Transforming the Hopper into a functional driving base required a multifaceted approach, engaging learners across different cognitive domains. Those inclined towards analytical thinking (quadrant A) excelled in meticulously planning the structural modifications required, carefully considering the placement of components to optimise stability and mobility. Individuals with a preference for practical thinking (quadrant B) demonstrated proficiency in executing the physical adjustments, utilising their hands-on competencies to assemble and configure the Hopper according to the desired specifications. Learners leaning towards relational thinking (quadrant C) actively collaborated with peers, exchanging ideas and leveraging collective knowledge to enhance the design and functionality of the driving base. Meanwhile, those inclined towards experimental thinking (quadrant D) embraced innovation, exploring unconventional modifications and testing alternative configurations to discover novel solutions.

Creating a programming code for forward movement in a straight line

Developing a programming code for forward movement in a straight line challenged learners to apply logical reasoning and sequential thinking to achieve precise control over the Hopper's motion. Individuals with a propensity for analytical thinking (quadrant A) excelled in deconstructing the movement into its constituent elements, meticulously crafting code that accounted for variables such as motor speed and duration of movement. Learners leaning towards practical thinking (quadrant B) demonstrated proficiency in implementing the code, carefully inputting commands and troubleshooting any errors that arose during testing. Those with a preference for relational thinking (quadrant C) collaborated with peers to refine the code, seeking feedback and incorporating suggestions to optimise performance. Meanwhile, individuals inclined towards experimental thinking (quadrant D) exhibited creativity in exploring alternative approaches to forward movement, experimenting with different code structures and parameters to achieve the desired outcome.

Creating a programming code for backward movement and turns

Developing a programming code for backward movement and turns presented learners with a more complex challenge, requiring them to integrate multiple commands to orchestrate coordinated motion. Learners leaning towards analytical thinking (quadrant A) excelled in devising systematic approaches to control backward movement and turns, carefully sequencing commands to ensure smooth transitions between different actions. Those with a preference for practical thinking (quadrant B) demonstrated proficiency in implementing the code, meticulously adjusting motor parameters and fine-tuning movement sequences to achieve accurate turns and reversals. Individuals leaning towards relational thinking (quadrant C) collaborated with peers to brainstorm creative solutions, leveraging collective insights to address challenges and optimise the code for efficient performance. Meanwhile, learners inclined towards experimental thinking (quadrant D) embraced a trial-and-error approach, iteratively refining the code through hands-on experimentation and learning from each iteration's outcomes.

Reflection

At the conclusion of the lesson, learners were tasked with composing a reflective worksheet (as seen in Appendix C) to assess their engagement with the robotics curriculum. This reflective exercise aimed to solicit insights into their learning experiences, including areas of difficulty, strengths and potential areas for improvement.

5.3.8.3 Observing the transformation

Transforming the Hopper into a functional driving base

At this point of the learning opportunity, learners exhibited varying degrees of success in transforming the Hopper into a functional driving base. Photo evidence 22 and 23 illustrate some of the adapted Hoppers. Those with a strong inclination towards hands-on activities (quadrant D) demonstrated confidence in disassembling and reconfiguring the Hopper, utilising their spatial intelligence to visualise and implement structural modifications. However, learners who favoured analytical thinking (quadrant A) appeared to face challenges in conceptualising the required adjustments, requiring additional guidance and prompting to grasp the mechanics of the transformation. Collaborative efforts (quadrant C) were observed among groups, with learners sharing insights and pooling resources to overcome obstacles encountered during the transformation process.

Photo evidence 22

Adapted Hopper

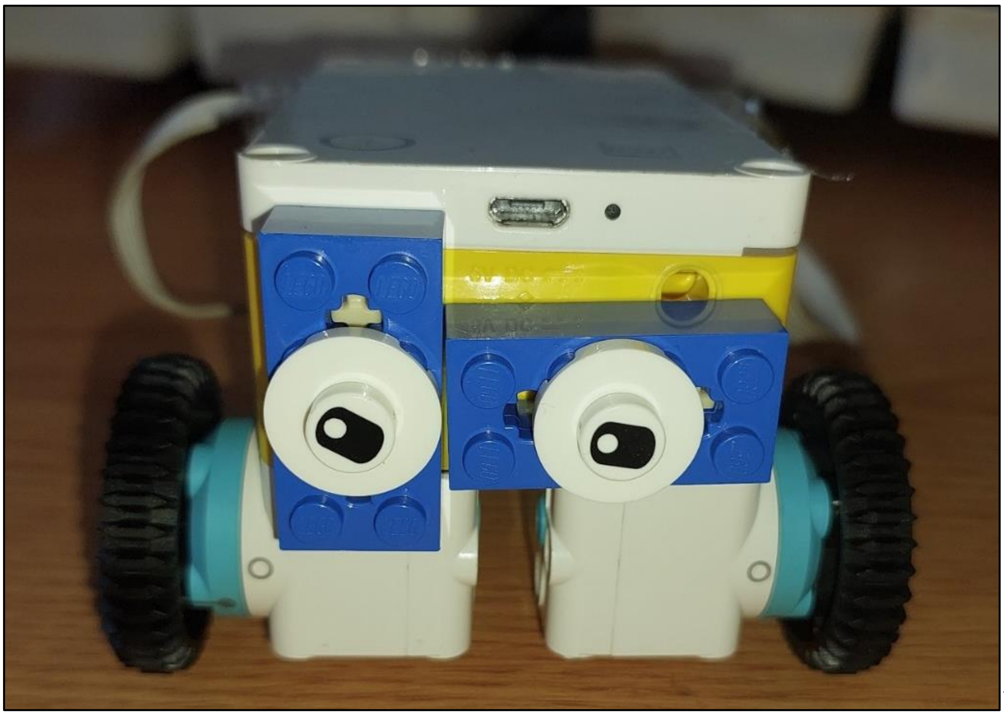


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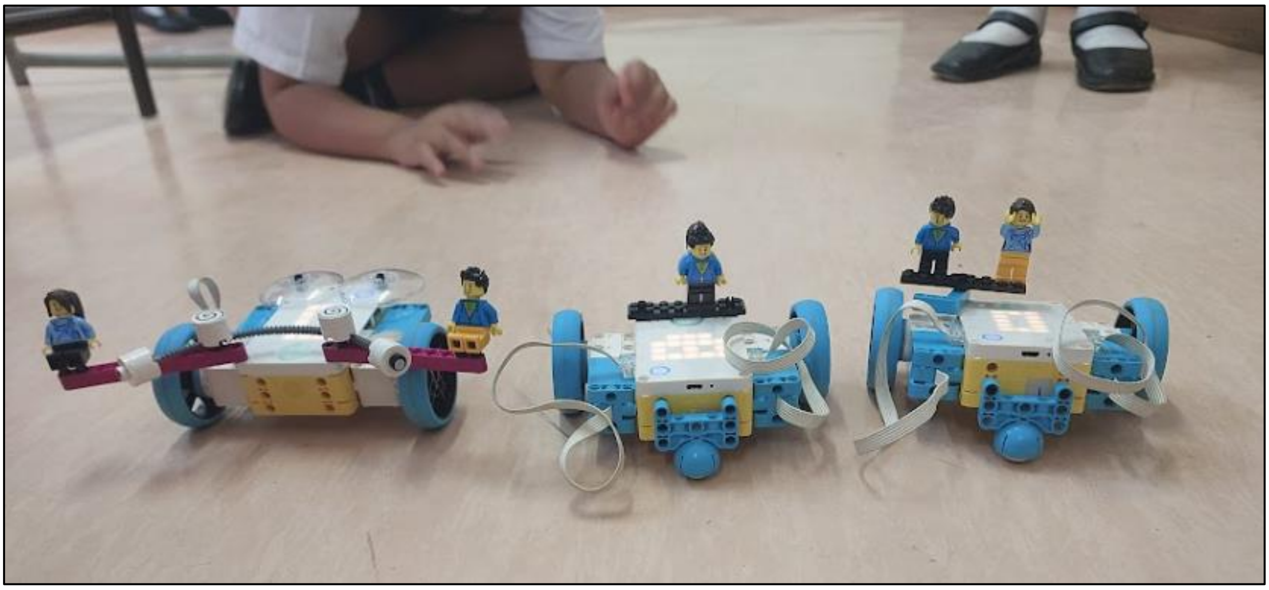
Photo evidence 23

Three adapted Hoppers



Creating a programming code for forward movement in a straight line

As learners endeavoured to create a programming code for forward movement in a straight line, distinct cognitive approaches became evident. Those inclined towards analytical thinking (quadrant A) meticulously dissected the problem, breaking down the motion into its constituent elements and devising precise commands to control the Hopper's trajectory. Learners with a practical orientation (quadrant B) demonstrated proficiency in implementing the code, executing commands with precision and fine-tuning motor parameters to achieve optimal performance. Relational thinking (quadrant C) was apparent as learners collaborated to troubleshoot errors and refine the code, exchanging ideas and offering support to peers encountering difficulties. Meanwhile, experimental thinking (quadrant D) was evident in learners' willingness to explore alternative coding strategies, embracing trial and error to discover innovative solutions for achieving forward movement.

Creating a programming code for backward movement and turns

The task of creating a programming code for backward movement and turns presented learners with a more intricate challenge, eliciting diverse cognitive approaches. Analytical thinkers (quadrant A) exhibited a methodical approach, carefully sequencing commands to orchestrate coordinated motion and navigate the

Hopper through turns with precision. Practical thinkers (quadrant B) demonstrated adeptness in implementing the code, adjusting motor parameters and fine-tuning commands to achieve smooth transitions between backward movement and turns. Relational thinking (quadrant C) fostered collaborative problem-solving efforts, with learners leveraging collective insights to overcome coding challenges and optimise the code for efficient performance. Experimental thinkers (quadrant D) embraced a hands-on, exploratory approach, experimenting with different coding structures and parameters to discover creative solutions for executing backward movement and turns.

Overall observations

I faced challenges in assisting learners in conceptualising complex movement sequences and ensuring they possessed a strong understanding of advanced coding blocks. As learners tackled increasingly intricate coding tasks, they experienced periods of frustration which necessitate supplementary assistance.

5.3.8.4 Reflecting on transformation

In the eighth cycle, learners were exposed to advanced coding constructs, necessitating a deeper engagement with complex concepts. This step underscored the significance of providing clear guidance and fostering innovative problem-solving competencies, as previously identified in cycle 7.

This lesson prompted a comprehensive review of the pedagogical approach. It was crucial to strike a balance between offering structured guidance and promoting independent exploration. To address potential challenges stemming from the complexity of the coding tasks, proactive measures such as peer collaboration and access to support resources were implemented. Additional resources, including online tutorials, reference materials and coding guides, were provided to support learners in comprehending and applying advanced coding concepts.

A key challenge involved assisting learners in grasping complex movement sequences and understanding advanced coding blocks, all while avoiding simply providing the answers. As learners engaged with more intricate coding tasks, they encountered frustration and required additional support. This highlighted the importance of ongoing support and scaffolding to help learners navigate through complex coding challenges successfully. To address this challenge, individualised support and assistance sessions were implemented, including one on one guidance, troubleshooting sessions and personalised feedback.

In the learners' reflective pieces, they highlighted various strengths, difficulties and areas for improvement related to their engagement with the robotics curriculum. Many expressed proficiencies in basic coding concepts and programming logic, often demonstrating these competencies during collaborative problem-solving activities. However, they also noted challenges in understanding and applying advanced coding constructs, indicating a need for further guidance and practice in these areas. Time management emerged as another common difficulty, with learners recognising the importance of managing their time effectively during project-based activities. Additionally, some learners struggled with complex movement sequences and programming algorithms, suggesting a need for additional support and guidance in these areas. Communication competencies were also identified as an area for improvement, particularly in terms of effectively sharing ideas and strategies within their groups. Overall, learners showed a willingness to improve and develop their competencies, highlighting their resilience and commitment to learning in the robotics curriculum.

The insights gained from this cycle will guide future planning and implementation. The overarching goal remains to cultivate technical proficiency, creative thinking and problem-solving competencies among learners by providing them with opportunities to interact with advanced coding constructs.

5.3.9 Cycle 9: Enhancing organisational competencies for LEGO® Spike Prime™ sets

5.3.9.1 Planning for transformation

The ninth cycle of the action research initiative expanded on the learners' initial experience with arranging and storing LEGO® Spike Prime™ robotic sets. The learning opportunity is as follow:

- Organising and packing LEGO® Spike Prime™ robotic sets efficiently

5.3.9.2 Acting to transform

Organising and packing LEGO® Spike Prime™ robotic sets efficiently

This task entails more than just placing LEGO® pieces into containers; it requires careful planning, spatial reasoning and an understanding of the components' functionalities to ensure efficient packing and easy access during future use. Learners are challenged to arrange the LEGO® Spike Prime™ robotic sets in a manner that facilitates quick retrieval of components while maximising storage space and minimising the risk of damage to delicate pieces.

To achieve this goal, learners need to categorise the components based on their types, sizes and functions. For instance, motors, sensors and bricks can be grouped together, with smaller pieces stored in compartments or dividers to prevent mixing and tangling. Engaging in this organisation process encourages learners to utilise relational thinking (quadrant C) as they consider the relationships between different components and how they can be logically grouped for efficient storage.

Furthermore, learners need to employ practical thinking (quadrant B) to determine the most space saving and accessible arrangement for the sets. This involves experimenting with different packing configurations to find the optimal solution. By considering factors such as the frequency of use of each component and the ease of access, learners can devise a packing strategy that streamlines the process of assembling and disassembling robots.

Collaborative efforts (quadrant C) also come into play during this task as learners work together to share ideas and strategies for organising the sets. Through teamwork and communication, learners can leverage each other's strengths and perspectives to develop a comprehensive packing plan that meets the needs of all users.

Overall, organising and packing LEGO® Spike Prime™ robotic sets efficiently not only enhances learners' organisational competencies but also fosters critical thinking, problem-solving and collaboration, all of which are essential competencies in the field of robotics and beyond.

5.3.9.3 Observing the transformation

Organising and packing LEGO® Spike Prime™ robotic sets efficiently

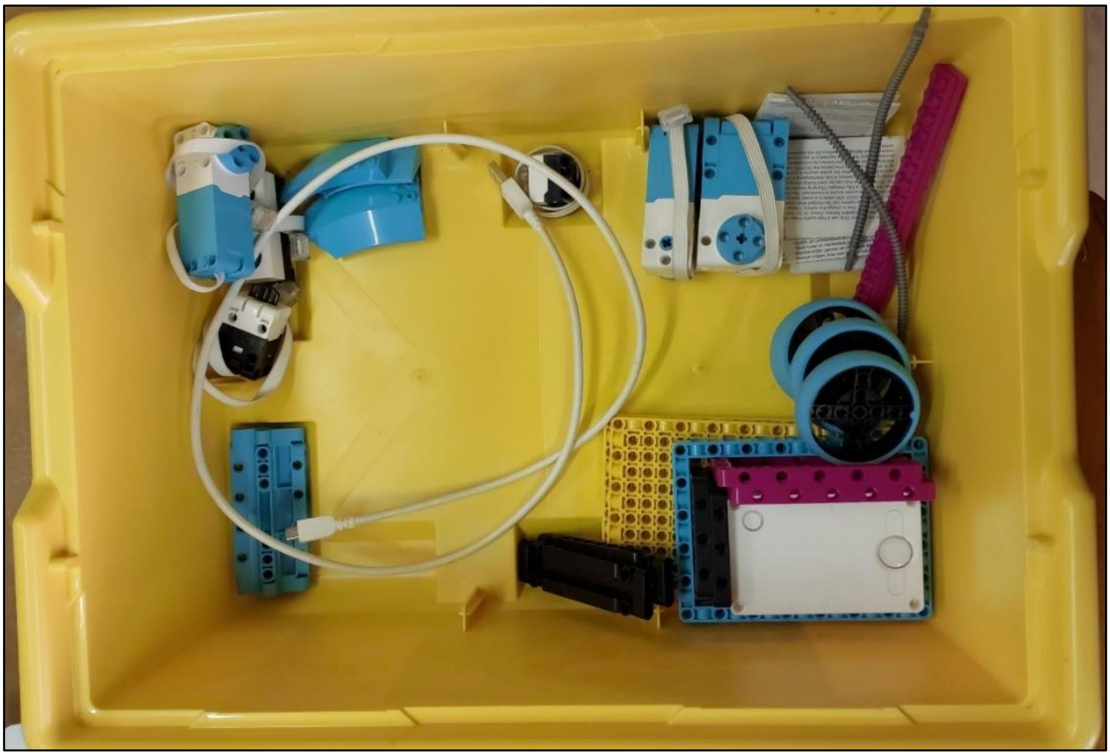
The lesson focused on organising and packing LEGO® Spike Prime™ robotic sets efficiently. As illustrated in Photo evidence 24 and 25, some learners packed the sets efficiently.

Photo evidence 24

LEGO® Spike Prime™ robotic set organisation

Photo evidence 25

LEGO® Spike Prime™ robotic set organisation



Other learners encountered various challenges, such as compartments being too full (as seen in Photo evidence 26) and engaged in problem-solving processes to overcome them. Many learners struggled to find personalised organisation systems that aligned with their individual preferences and working styles. Some learners required additional support in articulating their cognitive processes related to organisation, highlighting the need for differentiated learning opportunities and tailored assistance. An essential aspect of this learning opportunity was to ensure that the selected system optimised space efficiency while preserving the integrity of the robotic sets, fostering analytical thinking (quadrant A) as learners assessed dimensions and ease of manipulation.

Photo evidence 26

Semi-organised LEGO® Spike Prime™ set

Another unexpected challenge arose regarding the cleaning of the components within the set. Conventional moist towelettes were identified as the most efficacious solution for this task, reflecting practical thinking (quadrant B) as learners evaluated and selected the most suitable cleaning method. To address aesthetic damage incurred through wear and tear, learners and I collaboratively implemented clear self-adhesive tape as an affordable and replaceable adhesive covering for the hub. The transparent nature of the tape allowed for unimpeded utilisation of the hub's interface while providing a protective covering, demonstrating a strategic and practical approach to problem-solving.

Throughout the organisation process, learners were encouraged to cultivate an experimental approach, exploring diverse organisational methods and stimulating creative problem-solving. This experimental thinking (quadrant D) facilitated the development of individualised strategies tailored to learners' unique needs and preferences. Additionally, the promotion of collaborative discussions provided learners with a platform to share their organisational strategies, fostering relational thinking (quadrant C) as they exchanged ideas and explored alternative methods. Overall, the lesson provided valuable opportunities for learners to develop organisational competencies, critical thinking abilities and collaborative capabilities, contributing to their holistic growth and proficiency in robotics education.

5.3.9.4 Reflecting on transformation

In the ninth cycle, there was a noticeable progression in the learners' ability to effectively manage and coordinate LEGO® Spike Prime™ sets. This advancement was particularly evident in their improved communication, addressing a previously identified issue highlighted in their reflections during cycle 8. The ninth cycle underscored the significance of customising organisational systems to suit individual preferences and needs. This customisation ensured enhanced efficiency in upcoming projects, reflecting a deeper understanding and application of organisational competencies.

Upon reflection on this stage, it became evident that an individualised and adaptable method of organisation is paramount. By encouraging learners to articulate and refine their organisational strategies and offering them various choices, they were empowered to take ownership of their organisational processes. This approach not only improved their organisational competencies but also fostered autonomy and resourcefulness in handling robotic sets.

The knowledge acquired from this cycle has informed further planning and implementation. The goal remains to promote autonomy and resourcefulness in learners' handling of robotic sets by providing them with opportunities to enhance their organisational competencies. The reflective process continues to act as a catalyst for ongoing improvement, driving learners towards higher levels of organisation and efficiency in their work with LEGO® Spike Prime™ sets.

5.3.10 Cycle 10: Advancing geometric coding competencies with loops

5.3.10.1 Planning for transformation

The tenth cycle aimed to enhance learners' coding proficiency by introducing more intricate geometric shapes, building upon the groundwork established in cycle 8.

The learning opportunity for this lesson is as follows:

- Create a programming code that enables the Hopper to move through a maze

5.3.10.2 Acting to transform

Creating a programming code that enabled the Hopper to navigate through a maze presented learners with a multifaceted challenge that encompassed various aspects of robotics and coding. Initially, learners analysed the structure and layout of the maze, identifying potential obstacles, dead ends and the desired endpoint.

This analytical part of the learning opportunity required learners to break down the maze into manageable components, fostering analytical thinking (quadrant A) as they assessed the maze's complexity and devised a strategic approach. Once learners had comprehensively analysed the maze, they developed a coding algorithm that instructed the Hopper to travel through the maze efficiently. Learners engaged in experimental thinking (quadrant D) as they iteratively tested and refined their code, adjusting parameters and logic to improve the Hopper's navigation performance.

Creating a programming code for maze navigation also necessitated a strong understanding of coding concepts such as loops, conditionals and functions. Learners applied logical reasoning (quadrant A) to construct code that effectively directed the Hopper through the maze, incorporating decision making logic to handle branching paths and intersections. Additionally, learners explored advanced coding techniques such as pathfinding algorithms to optimise the Hopper's route through the maze, further enhancing their problem-solving competencies and computational thinking abilities.

Throughout the process of creating the programming code, learners were encouraged to collaborate and share ideas, fostering relational thinking (quadrant C) as they engaged in discussions, offered feedback and collaborated on troubleshooting challenges. By working collaboratively, learners benefited from diverse perspectives and collective problem-solving efforts, leading to more robust and innovative solutions. Overall, creating a programming code that enabled the Hopper to move through a maze provided learners with a rich learning experience that integrated analytical thinking, experimental thinking, logical reasoning and collaboration. Through this challenge, learners developed essential coding competencies, problem-solving abilities and teamwork dynamics, preparing them for real world applications in robotics and technology.

5.3.10.3 Observing the transformation

Observing the lesson aimed at creating a programming code for the Hopper to navigate through a maze provided insights into learners' cognitive engagement and problem-solving abilities. Initially, learners exhibited analytical thinking as they carefully examined the maze layout, identifying potential obstacles and determining the optimal path for the Hopper to traverse (quadrant A). Throughout the coding process, learners demonstrated experimentation by testing different algorithms and adjusting parameters to improve the Hopper's navigation efficiency, showcasing their willingness to explore innovative solutions (quadrant D). Logical thinking was evident as learners devised decision making structures within the code, such as obstacle detection routines and pathfinding algorithms, to guide the Hopper through the maze with precision (quadrant B). Additionally, relational thinking flourished as learners collaborated with peers, sharing insights and troubleshooting challenges collectively to enhance their understanding and refine their coding strategies (quadrant C). Overall, the activity fostered holistic cognitive development, nurturing learners' analytical, experimental, logical and relational thinking competencies in the context of robotics programming.

The challenges faced in the learning setting involved the need to encourage learners to independently engage in coding exploration and experimentation for an extended period. Furthermore, significant attention was given to addressing existing challenges related to alignment and motor synchronisation. Problems emerged regarding the white balls attached as the third wheel, which showed a vulnerability to gathering dust and consequently obstructing movement by creating areas of reduced roundness. To address this challenge, a practical intervention was implemented by replacing the previously mentioned white balls with glass marbles. In Photo evidence 27, learners were observed engaging in the assembly of the new Hopper.

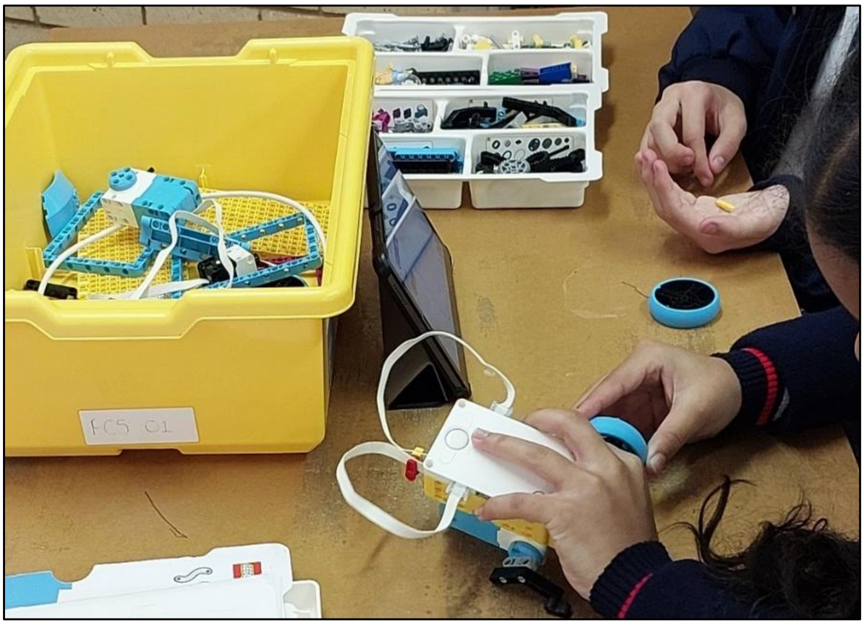
Photo evidence 27

Assembly of the new Hopper

Subsequently, in a distinct set of visual records marked as "Photo evidence 28," these learners were observed actively engaged in the process of coding to attain their specified objectives.

Photo evidence 28

Coding the new Hopper



On the other hand, a benefit of the teaching effort was evident in increased learner involvement. The increased involvement led to advancements in the participants' learning development. The learners' ability to construct personalised obstacles (as seen in Photo evidence 29) was particularly impressive, as it improved their understanding and application of coding principles.

Photo evidence 29

Hopper maze

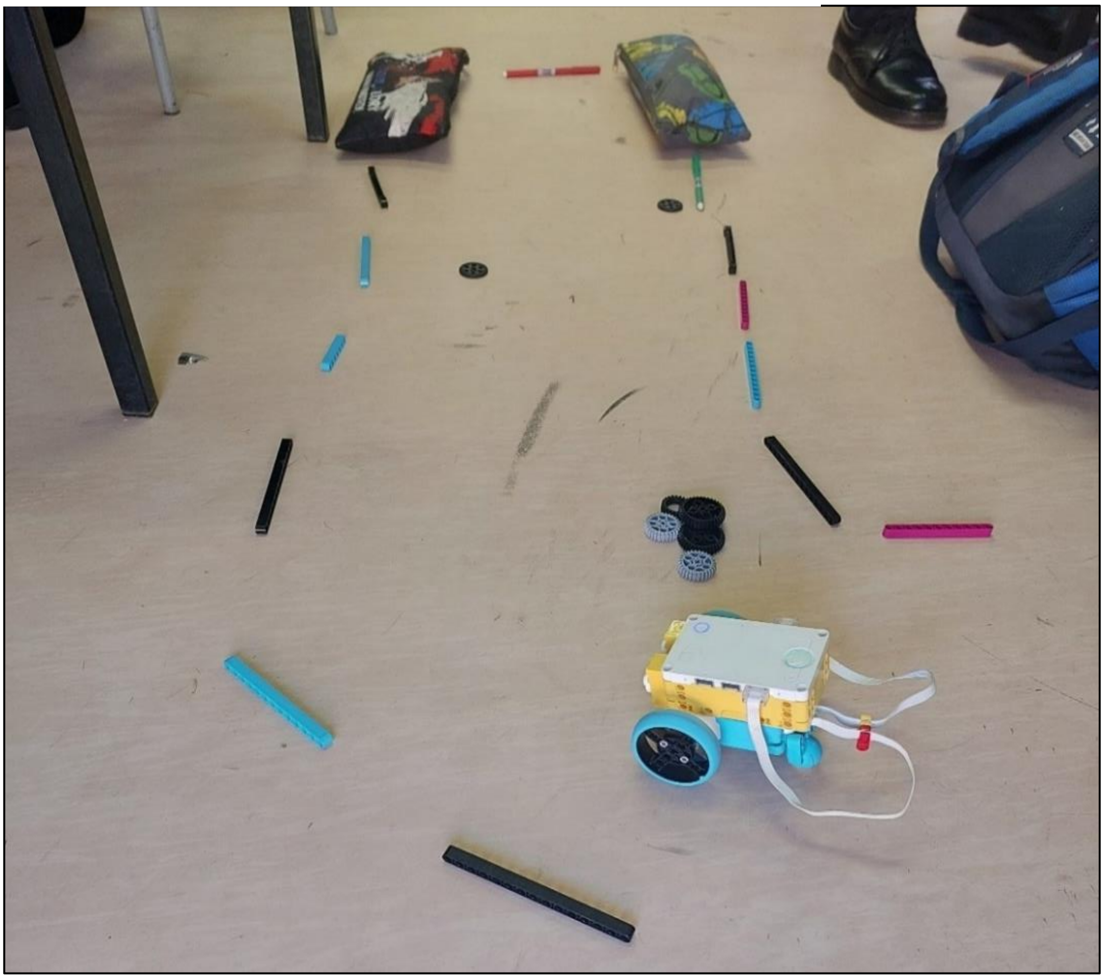
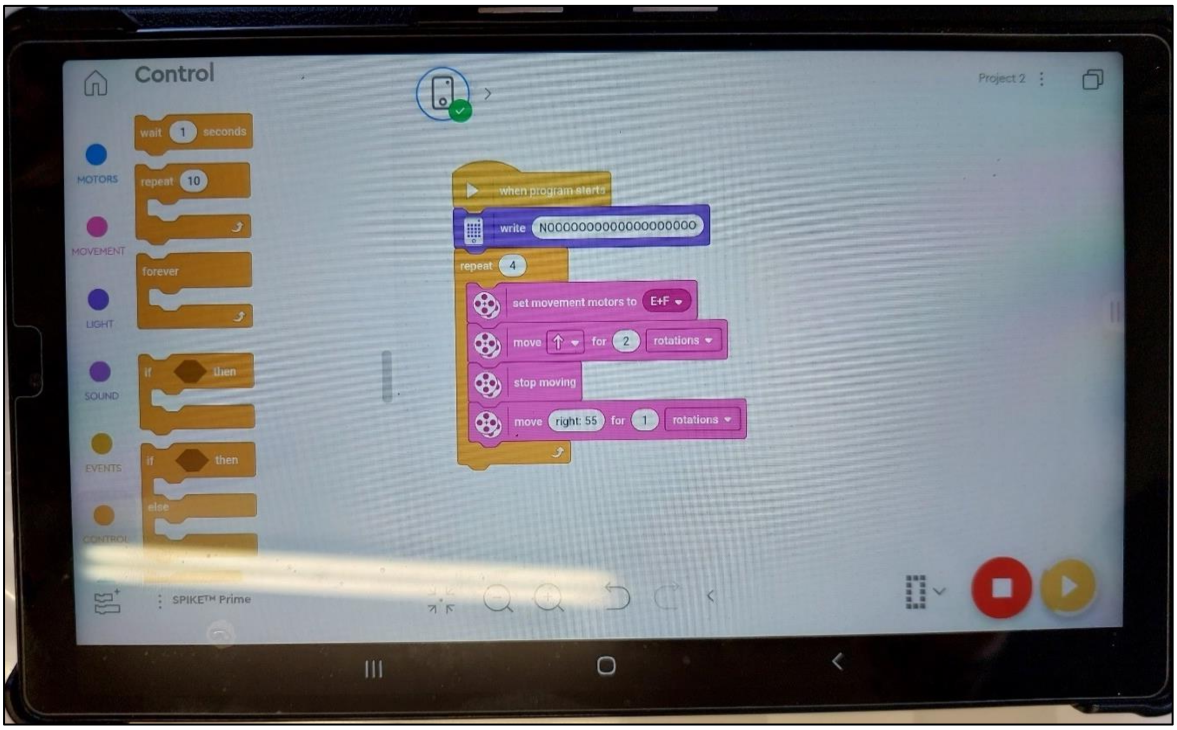


Photo evidence 30 depicts the carefully constructed programming code created by the group, with the specific purpose of activating the motors and propelling the Hopper in a forward direction. The coding project pursued by these learners is remarkable for incorporating a unique message, specifically "Nooooooo," which is programmed to precede the start of motor activity. The deliberate inclusion of a written prompt demonstrates the learners' intention to add a personalised and expressive element to the programming code execution process, giving their technological creation a distinct and individualised touch.

Photo evidence 30

Programming code of the "new" Hopper



5.3.10.4 Reflecting on transformation

In the coding session captured in Photo evidence 27, learners engaged in programming the new Hopper model, demonstrating their growing proficiency in coding and robotics. This lesson marked a significant step forward in their understanding and application of coding concepts, particularly with a new robotic model.

One strength of the lesson was the evident improvement in learners' ability to grasp complex coding concepts. They showed increased proficiency in decomposing movement requirements into logical sequences and devising precise commands to control the Hopper's actions. This reflects a growing understanding of computational thinking and problem-solving competencies.

Collaboration was another strength, with learners actively sharing ideas, troubleshooting together and collectively refining their code. This collaborative approach not only enhanced their coding competencies but also promoted teamwork and communication; essential competencies in both robotics and broader contexts.

However, one challenge of the lesson was the complexity of the task, especially for learners who were still developing their coding competencies. Some learners found it challenging to translate their ideas into functional code, requiring additional guidance and support.

Another challenge was ensuring that each learner had the opportunity to actively participate and contribute to the coding process. It was essential to provide individualised support and guidance to ensure that all learners could engage meaningfully with the task.

Overall, the lesson was successful in advancing learners' coding competencies and fostering a collaborative and engaging learning environment. The strengths observed, such as improved coding proficiency and effective collaboration, indicated that learners were progressing well in their coding journey.

5.3.11 Cycle 11: Iterative prototyping and enhanced coding proficiency

5.3.11.1 Planning for transformation

During this cycle, learners expanded upon their prior knowledge of designing and coding by designing and creating a programming code for "mini cars." The emphasis was on iterative prototyping, enabling learners to enhance and optimise their designs through the utilisation of their prior experiences. Additionally, they were exposed to more sophisticated coding principles to improve their coding expertise.

They were as follows:

- Designing possible prototypes
- Evaluating and selecting a promising solution
- Creating a prototype
- Creating a programming code to move the car
- Testing and troubleshooting
- Making improvements to and releasing the final product

5.3.11.2 Acting to transform

Designing possible prototypes

During this learning opportunity, learners engaged in creative brainstorming sessions to generate a variety of design concepts for their car project. The instructional approach maintained its focus on pair work, fostering collaboration between pairs and promoting experiential learning. They explored diverse ideas, considering factors such as functionality, aesthetics and innovation. Analytical thinkers (quadrant A) may have meticulously analysed the feasibility and practicality of each design, while those with a preference for experimental thinking (quadrant D) may have proposed unconventional and out of the box concepts. Collaborative discussions allowed learners to leverage relational thinking (quadrant C), building upon each other's ideas and refining their designs collectively.

Evaluating and selecting a promising solution

Following the brainstorming, learners evaluated and selected a promising solution from among the proposed prototypes. They considered criteria such as functionality, cost effectiveness and innovation to make informed decisions. Analytical thinking (quadrant A) played a crucial role as learners critically assessed the strengths and weaknesses of each design concept. Practical thinkers (quadrant B) focused on selecting a solution that met project requirements and could be feasibly implemented within given constraints.

Creating a prototype

In this learning opportunity, learners translated their selected design concept into a physical model. Practical thinking (quadrant B) guided learners as they selected appropriate materials and tools for construction. Hands-on experimentation and problem-solving competencies were essential as learners navigated challenges and refined their prototypes. Those inclined towards experimental thinking (quadrant D) embraced trial and error approaches to optimise their designs and explore alternative configurations.

Creating a programming code to move the car

Once the prototypes were constructed, learners developed programming codes to control the movement of their cars. Logical thinking (quadrant A) guided learners as they devised algorithms to command the motors and sensors, ensuring precise and responsive performance. Iterative testing and troubleshooting were essential components of this learning opportunity, with learners analysing feedback from their prototypes and making adjustments to improve functionality.

Testing and troubleshooting

During this learning opportunity, learners conducted extensive testing to evaluate the performance of their prototypes. They identified issues and implemented troubleshooting strategies to address them effectively. Collaborative problem-solving efforts were facilitated by relational thinking (quadrant C), as learners collaborated with peers to identify and resolve challenges collectively. Feedback and peer review sessions provided valuable insights, enabling learners to refine their prototypes and enhance their performance.

Making improvements to and releasing the final product

Finally, learners made improvements based on feedback and released the final product. They celebrated their achievements and showcased their collaborative efforts. The iterative nature of the design process fostered continuous learning and growth, empowering learners to apply their newfound competencies and knowledge to future projects.

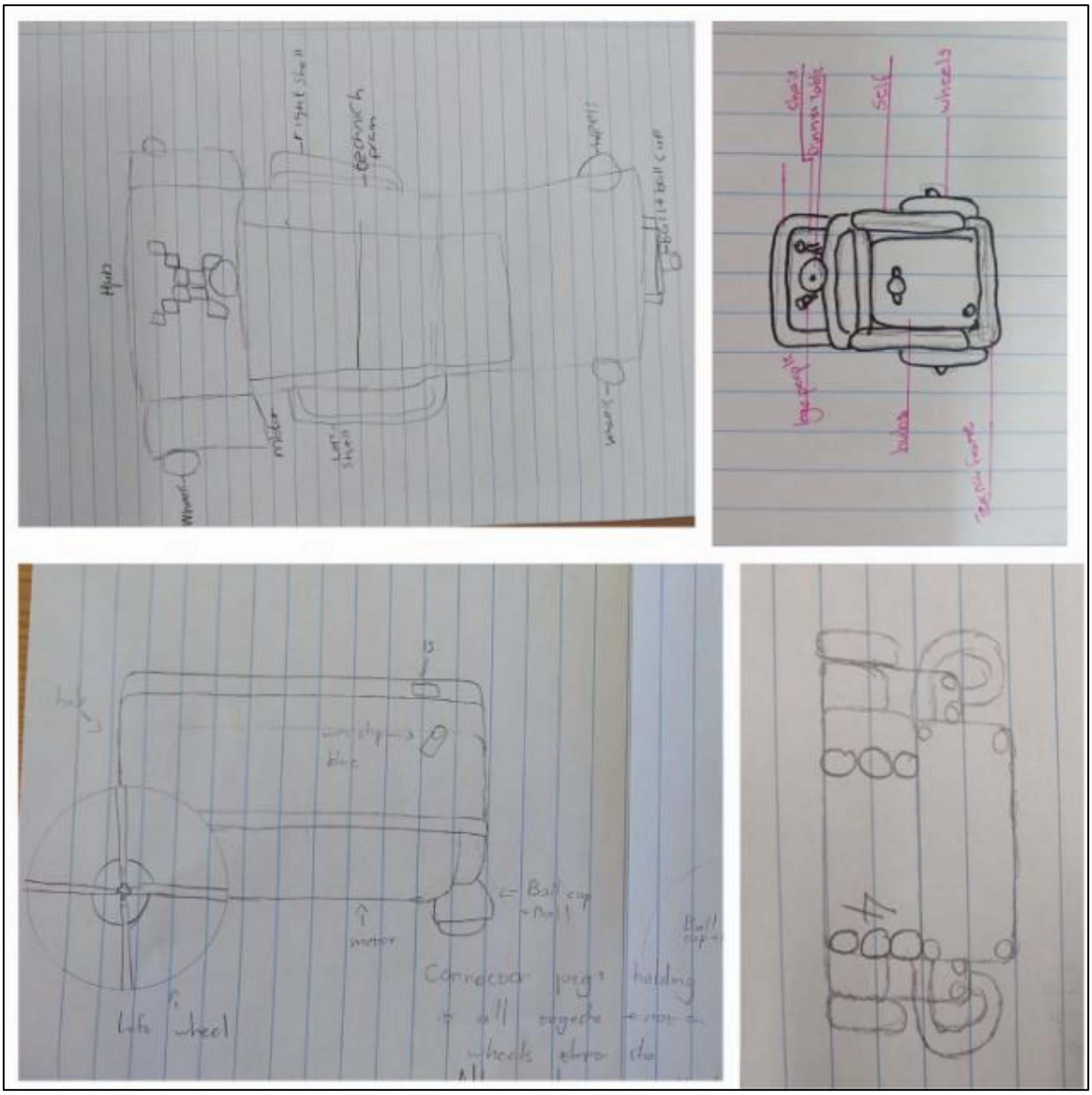
5.3.11.3 Observing the transformation

Designing possible prototypes

During this learning opportunity, learners demonstrated varying degrees of creativity and critical thinking in generating design concepts for their car project, as seen in Photo evidence 31.

Photo evidence 31

Car designs



Analytical thinkers (quadrant A) were observed carefully analysing the feasibility and practicality of different design ideas, considering factors such as functionality and cost effectiveness. Those inclined towards practical thinking (quadrant B) focused on selecting design concepts that aligned with project requirements and constraints. Learners with a preference for experimental thinking (quadrant D) exhibited creativity and innovation, proposing unconventional and inventive design solutions. Collaborative discussions were evident, fostering relational thinking (quadrant C) as learners shared ideas, provided feedback to each other, and collaborated on refining their design concepts. In Photo evidence 31 various design concepts created by learners were displayed, showcasing the diverse range of ideas generated during the ideation learning opportunity.

Evaluating and selecting a promising prototype

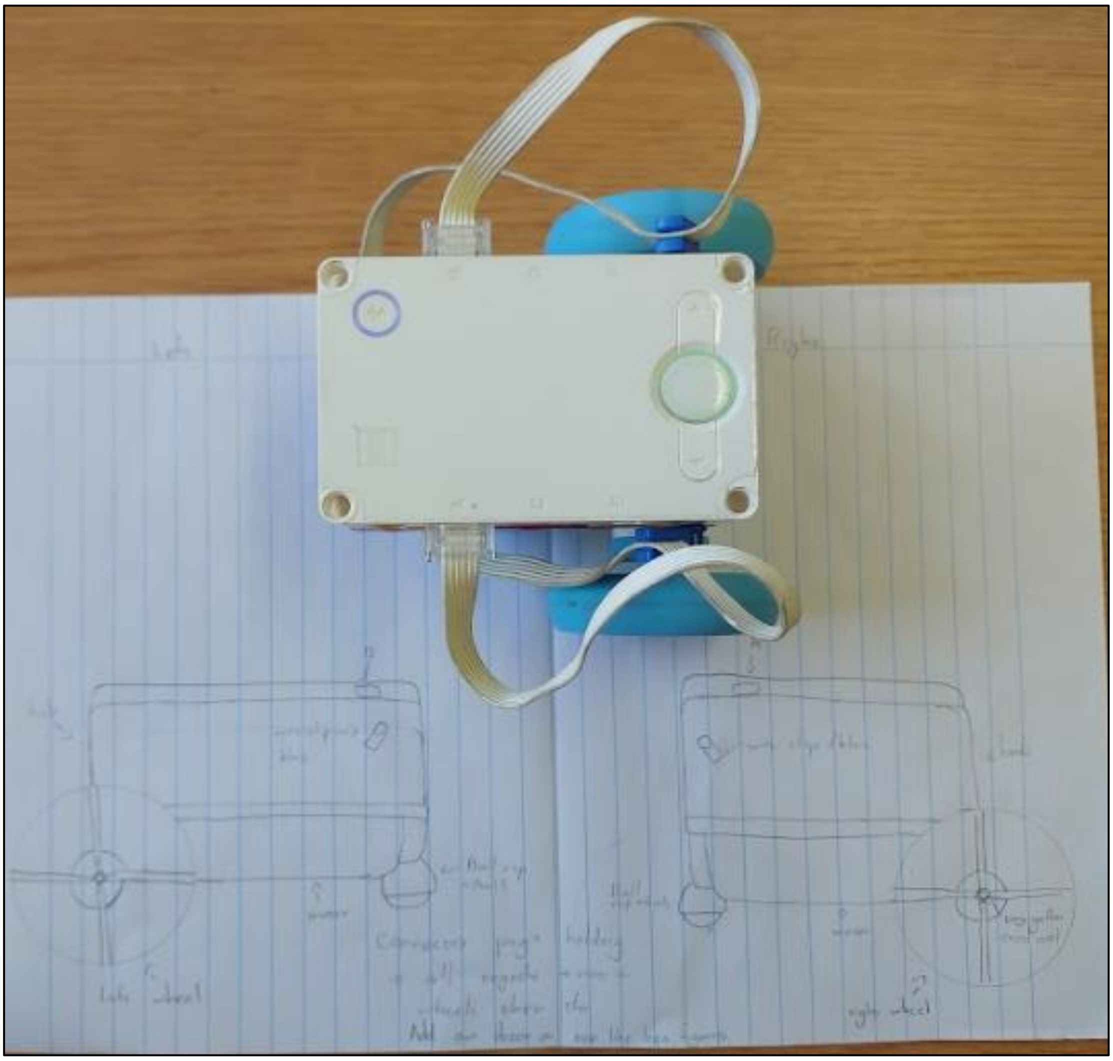
In this learning opportunity, learners engaged in critical evaluation and decision-making processes to select the most promising solution from among the proposed design concepts. Analytical thinkers (quadrant A) demonstrated a systematic approach to evaluating the strengths and weaknesses of each design, considering criteria such as functionality, cost effectiveness and innovation. Practical thinkers (quadrant B) focused on selecting a solution that met project requirements and could be feasibly implemented within given constraints. Collaborative discussions allowed learners to leverage relational thinking (quadrant C), building consensus and making informed decisions collectively.

Creating a prototype

Learners demonstrated hands-on competencies and problem-solving abilities as they translated their selected design concept into physical prototypes. Practical thinkers (quadrant B) were observed selecting appropriate materials and tools for construction, focusing on building prototypes that were sturdy and functional as illustrated in Photo evidence 32.

Photo evidence 32

Functional car with design



Experimental thinkers (quadrant D) particularly stood out, as they embraced trial and error approaches. They explored alternative configurations, refining their prototypes through iterative experimentation. This approach allowed them to test different ideas, make improvements and ultimately create more innovative and effective solutions, while demonstrating creativity as illustrated in Photo evidence 33 and 34.

Photo evidence 33

Creative car with design

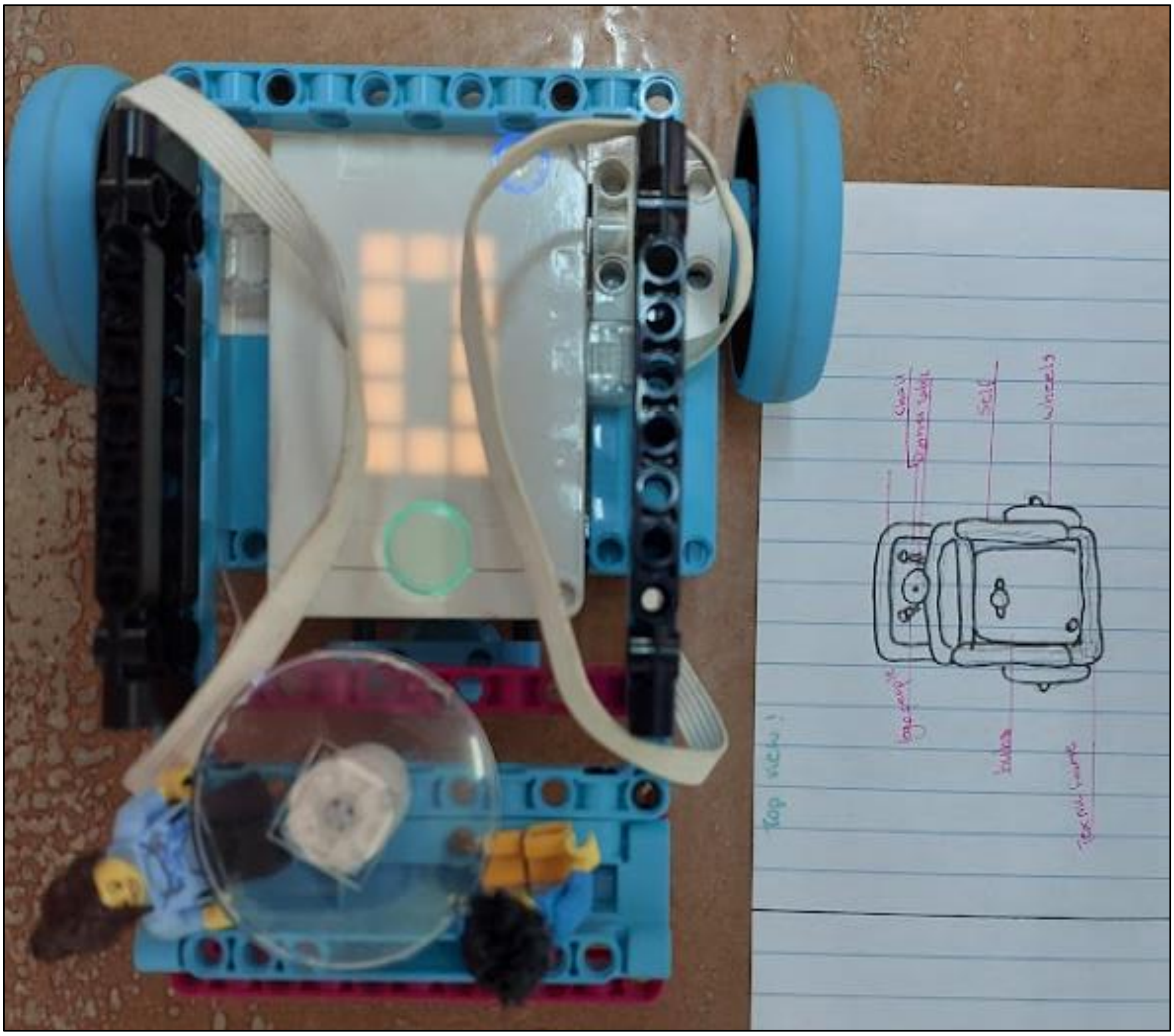
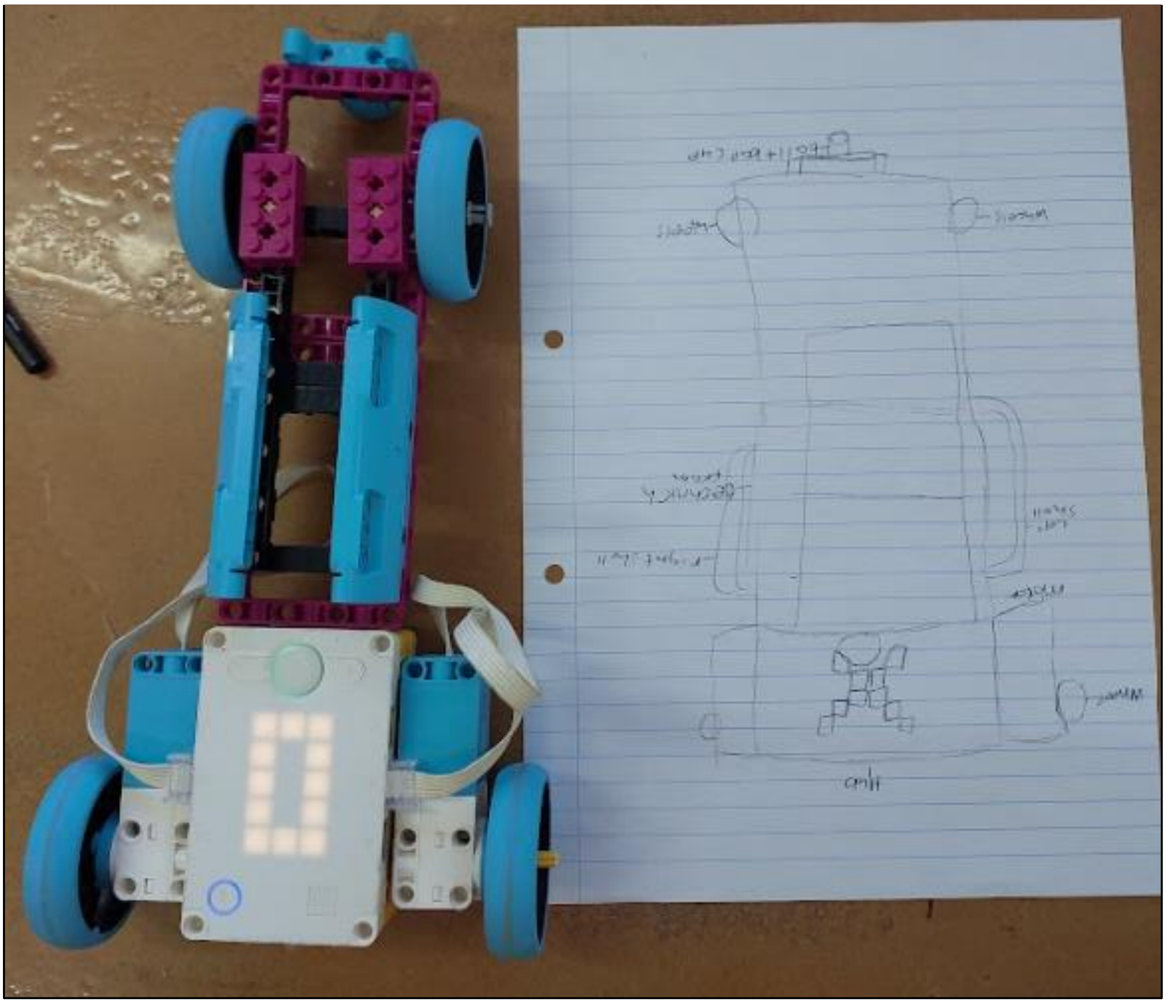


Photo evidence 34

Creative car with design



Analytical thinkers (quadrant A) meticulously analysed the performance of their prototypes, identifying areas for improvement and making adjustments accordingly. Collaborative efforts were evident, with learners engaging in relational thinking (quadrant C) as they worked together to troubleshoot challenges and refine their prototypes.

Creating a programming code to move the car

During this learning opportunity, learners developed programming codes to control the movement of their car prototypes. Logical thinking (quadrant A) guided learners as they devised algorithms to command the motors and sensors, ensuring precise and responsive performance. Hands-on experimentation and problem-solving competencies were essential as learners navigated challenges and refined their codes. Practical thinkers (quadrant B) focused on creating a code that was efficient and easy to implement, while experimental thinkers (quadrant D) explored creative coding solutions and experimented with different programming techniques. Collaborative problem-solving efforts were facilitated by relational thinking (quadrant C), as learners collaborated with peers to identify and resolve coding challenges collectively.

Testing and troubleshooting

In this learning opportunity, learners conducted extensive testing to evaluate the performance of their prototypes and programming codes. They identified issues and implemented troubleshooting strategies to address them effectively. Analytical thinkers (quadrant A) were observed systematically analysing the feedback from their tests, identifying root causes of issues and proposing solutions. Practical thinkers (quadrant B) focused on practical solutions to resolve issues efficiently, while experimental thinkers (quadrant D) embraced trial and error approaches to find innovative solutions. Collaborative problem-solving efforts were evident, with learners engaging in relational thinking (quadrant C) as they shared insights, provided support to each other and worked together to overcome challenges.

Making improvements to and releasing the final product

Finally, learners made improvements based on feedback and prepared to release the final product. They celebrated their achievements and showcased their collaborative efforts. Analytical thinkers (quadrant A) were observed systematically analysing feedback and making data driven decisions to prioritise improvements. Practical thinkers (quadrant B) focused on implementing practical solutions to enhance the functionality and usability of the final product. Experimental thinkers (quadrant D) embraced innovation, exploring creative improvements and pushing the boundaries of design possibilities. Collaborative efforts were evident, with learners engaging in relational thinking (quadrant C) as they shared ideas, provided feedback and worked together to make the final product a success.

5.3.11.4 Reflecting on transformation

Cycle 11 presented a pivotal stage in the learners' design and coding process as they enhanced their "mini cars" through iterative prototyping. This step highlighted the importance of ongoing enhancement and the implementation of more sophisticated coding principles. Learners were encouraged to experiment with different design ideas and coding strategies, fostering creativity and innovation. The iterative nature of the design process allowed learners to refine their prototypes based on feedback, promoting a sense of ownership and accomplishment in their work. Collaborative efforts were also a strength of the lesson, encouraging teamwork and communication competencies as learners worked together to solve problems and improve their prototypes. However, the complexity of the coding tasks posed a challenge, particularly for less experienced learners. Some struggled to grasp the more sophisticated coding principles and required additional support. To address this challenge, individualised support and guidance were provided, including one on one instruction and peer mentoring. Additionally, scaffolding techniques, such as breaking down complex tasks into smaller, more manageable steps, were employed to support learners' understanding. Managing the iterative design process and incorporating feedback effectively was also challenging for some learners. To overcome this challenge, structured feedback sessions were implemented allowing learners to receive constructive criticism and guidance on how to improve their prototypes.

5.3.12 Cycle 12: Enhancing planning and design (3 weeks)

5.3.12.1 Planning for transformation

During this stage of the action research cycle, learners focused primarily on improving their competencies in planning and designing. The central focus of this project emerged from the active involvement of learners in the process of conceptualisation and development. They were given the assignment to create either a miniature golf course or a simulated pet. An important requirement in this creative project was to use recyclable materials to build the courses or pets, while also considering how to incorporate LEGO® pieces into the designed spaces. In the planning step, specific learning objectives related to planning and design were defined. This was done alongside the creation of learning materials that explained effective planning strategies and sustainable design principles. A crucial component of this stage involved a briefing session, during which project requirements were delineated and the importance of sustainability in design was emphasised.

The learning opportunities included:

- Analysing and evaluating different design concepts for a miniature golf course or a simulated pet, considering factors such as functionality, aesthetics and sustainability.
- Planning and designing a creative and sustainable miniature golf course or simulated pet using recyclable materials and incorporating LEGO® pieces into the design.
- Applying effective planning strategies and sustainable design principles in the development of the project, ensuring that the final product met specified requirements and demonstrated innovative design solutions.
- Collaborating with peers to share ideas, provide feedback and refine design concepts, fostering a collaborative and creative learning environment.
- Presenting the final design concept, highlighting the thought process, planning strategies and innovative design elements incorporated into the project, and reflecting on the importance of sustainability in design.

5.3.12.2 Acting to transform

Analysing and evaluating different design concepts

During this stage, learners engaged in a thorough analysis and evaluation of various design concepts for their miniature golf course or simulated pet. They considered factors such as functionality, aesthetics and sustainability, demonstrating analytical (quadrant A) and practical (quadrant B) thinking. Learners meticulously assessed each concept, breaking down the design elements to identify strengths and weaknesses. This process encouraged them to think critically about the functionality of their designs and the aesthetic appeal they wanted to achieve. Additionally, learners evaluated the sustainability of each concept, considering the environmental impact of their choices and seeking ways to minimise waste.

Planning and designing a creative and sustainable project

After evaluating the design concepts, learners proceeded to plan and design their miniature golf course or simulated pet. They applied effective planning strategies and sustainable design principles, showcasing their creative (quadrant D) and practical (quadrant B) thinking competencies. Learners utilised recyclable materials and incorporated LEGO® pieces into their designs, demonstrating innovative solutions to create functional and aesthetically pleasing projects. They considered the feasibility of their designs and the practicality of implementing them, ensuring that their final projects would meet specified requirements.

Applying effective planning strategies and sustainable design principles

In developing their projects, learners applied effective planning strategies and sustainable design principles. They organised their thoughts and developed clear plans for executing their designs, demonstrating analytical (quadrant A) and practical (quadrant B) thinking. Learners also considered the environmental impact of their choices, seeking innovative ways to minimise waste and maximise resource efficiency. By applying sustainable design principles, learners ensured that their projects were not only functional and aesthetically pleasing but also environmentally friendly.

Collaborating with peers

Throughout the process, learners collaborated with their peers to share ideas, provide feedback, and refine design concepts. This collaborative effort fostered a creative and supportive learning environment, encouraging learners to explore new ideas and take risks. Collaboration also promoted relational thinking (quadrant C), as learners worked together to improve their designs and incorporate feedback from their peers. By collaborating with their peers, learners gained valuable insights and perspectives, enhancing the quality of their final projects.

Presenting the final design concept

Finally, learners presented their final design concepts, highlighting their thought process, planning strategies and innovative design elements. They reflected on the importance of sustainability in design, recognising the impact of their choices on the environment and future generations. Presenting their projects allowed learners to showcase their creativity, critical thinking and problem-solving competencies; demonstrating their ability to apply these competencies in a real-world context.

5.3.12.3 Observing the transformation

Analysing and evaluating different design concepts

At the onset of the learning opportunity, learners engaged in a thoughtful analysis and evaluation of various design concepts for their miniature golf course or simulated pet. They demonstrated strong analytical competencies (quadrant A) as they carefully considered factors such as functionality, aesthetics, and sustainability. Learners actively participated in discussions, sharing their insights and perspectives on each design concept. This collaborative approach not only encouraged critical thinking but also fostered a sense of creativity and innovation among the learners.

Planning and designing a creative and sustainable project

As the lesson progressed, learners began planning and designing their miniature golf course or simulated pet. They showed a high level of creativity (quadrant D) in their designs, incorporating recyclable materials and LEGO® pieces to create unique and sustainable projects. Photo evidence 35 to 39 serve as illustrative examples showcasing simulated pet designs. These visual representations offer insight into the creative endeavours of the learners, providing tangible manifestations of their conceptualisations and design processes. Photo evidence 37 to 39 exemplifies the miniature golf courses meticulously designed by learners. These visual representations offer a glimpse into the intricacy and creativity embedded within the learners' designs, showcasing their ability to conceptualise and construct engaging and interactive recreational spaces.

Photo evidence 35

Simulated pet design

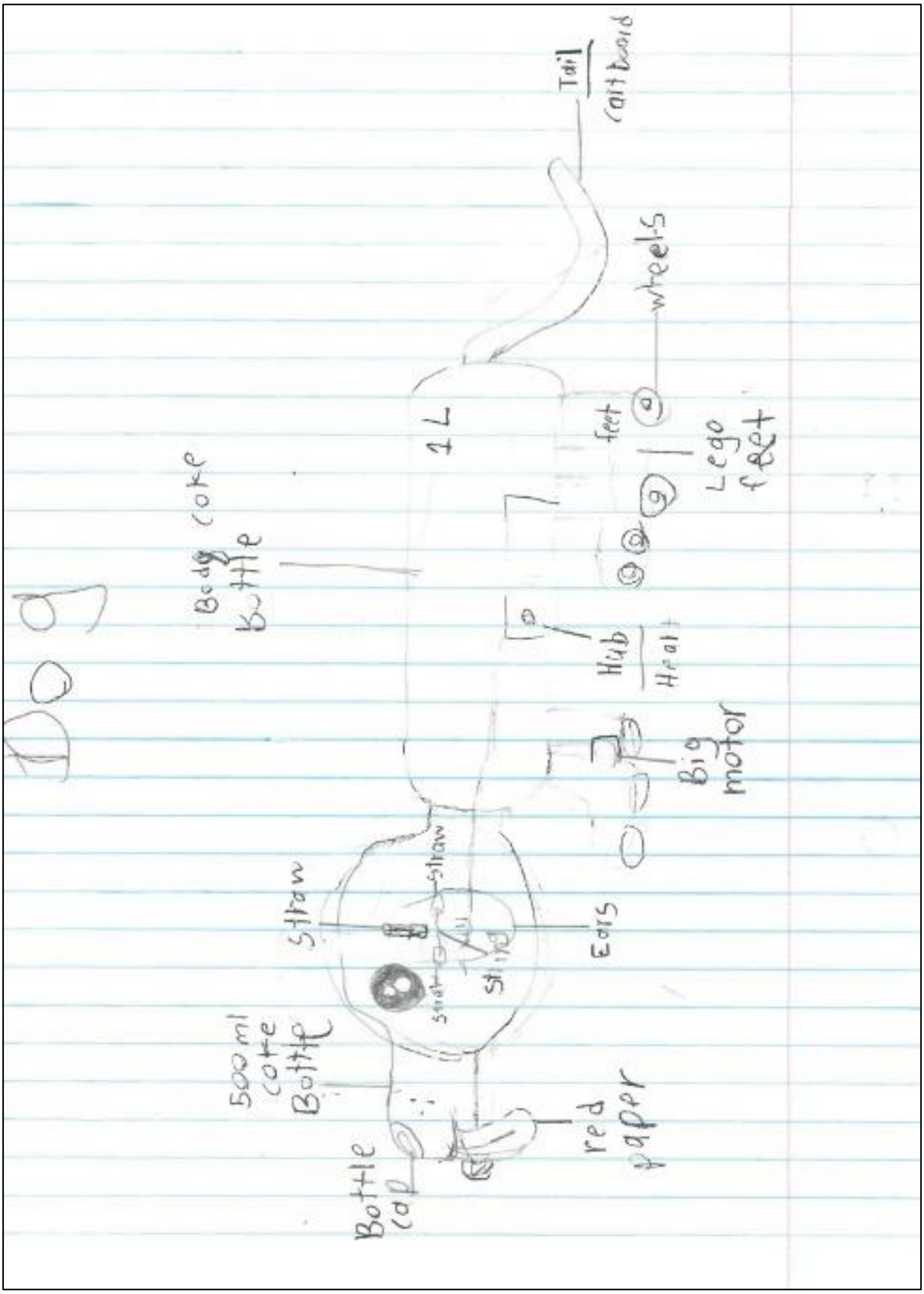


Photo evidence 36

Simulated pet design

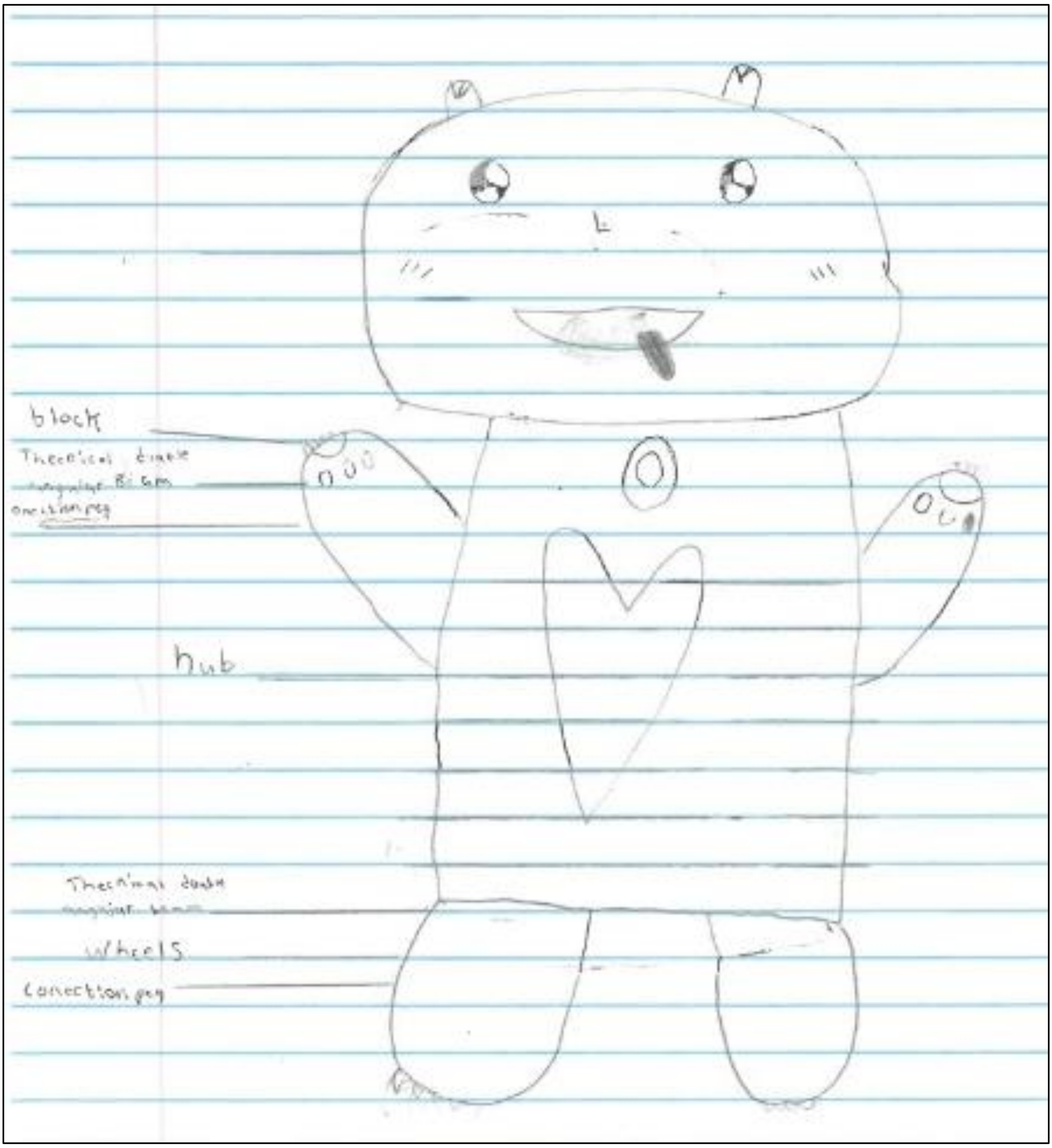


Photo evidence 37

Miniature golf course design

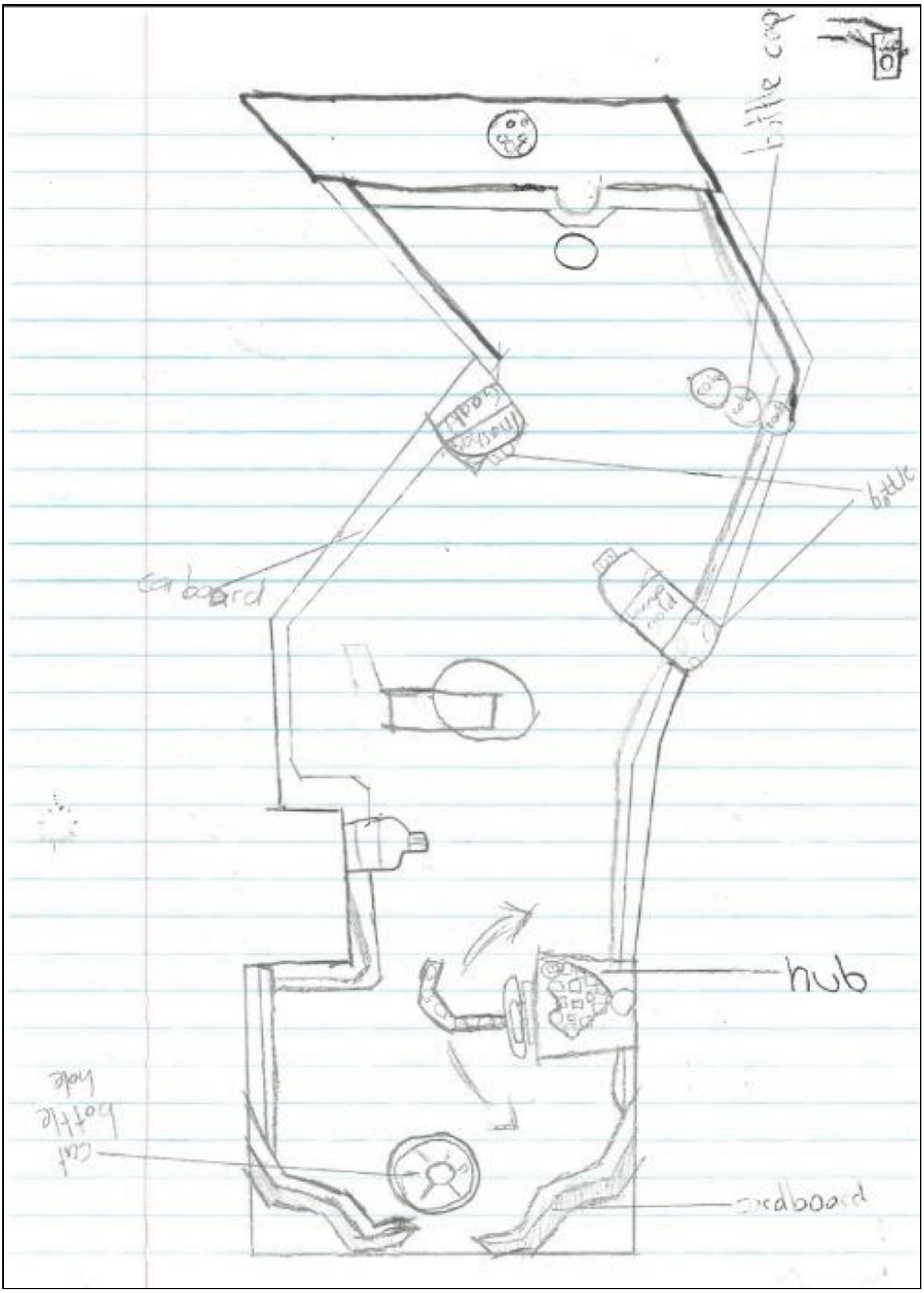


Photo evidence 38

Miniature golf course design

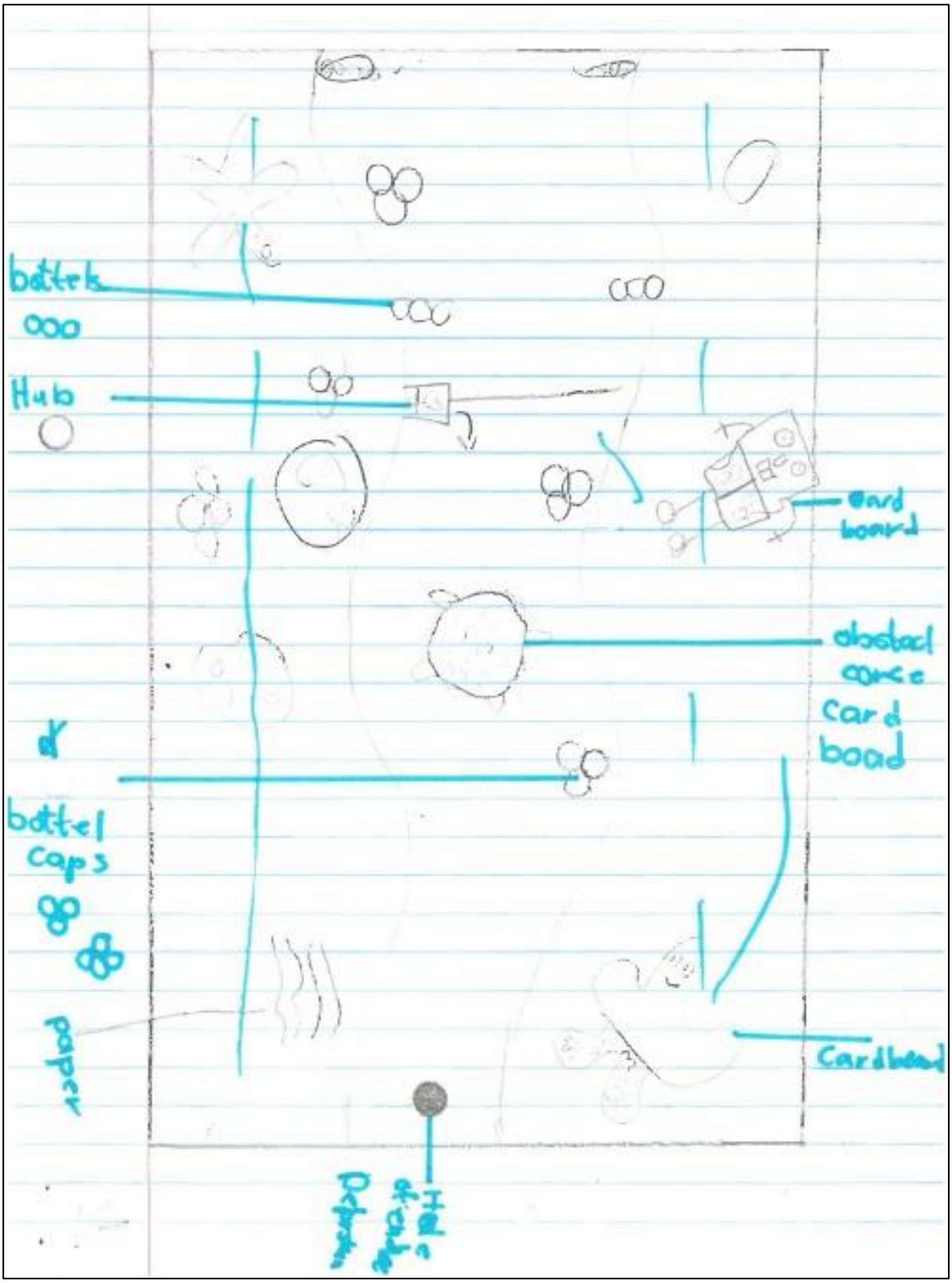
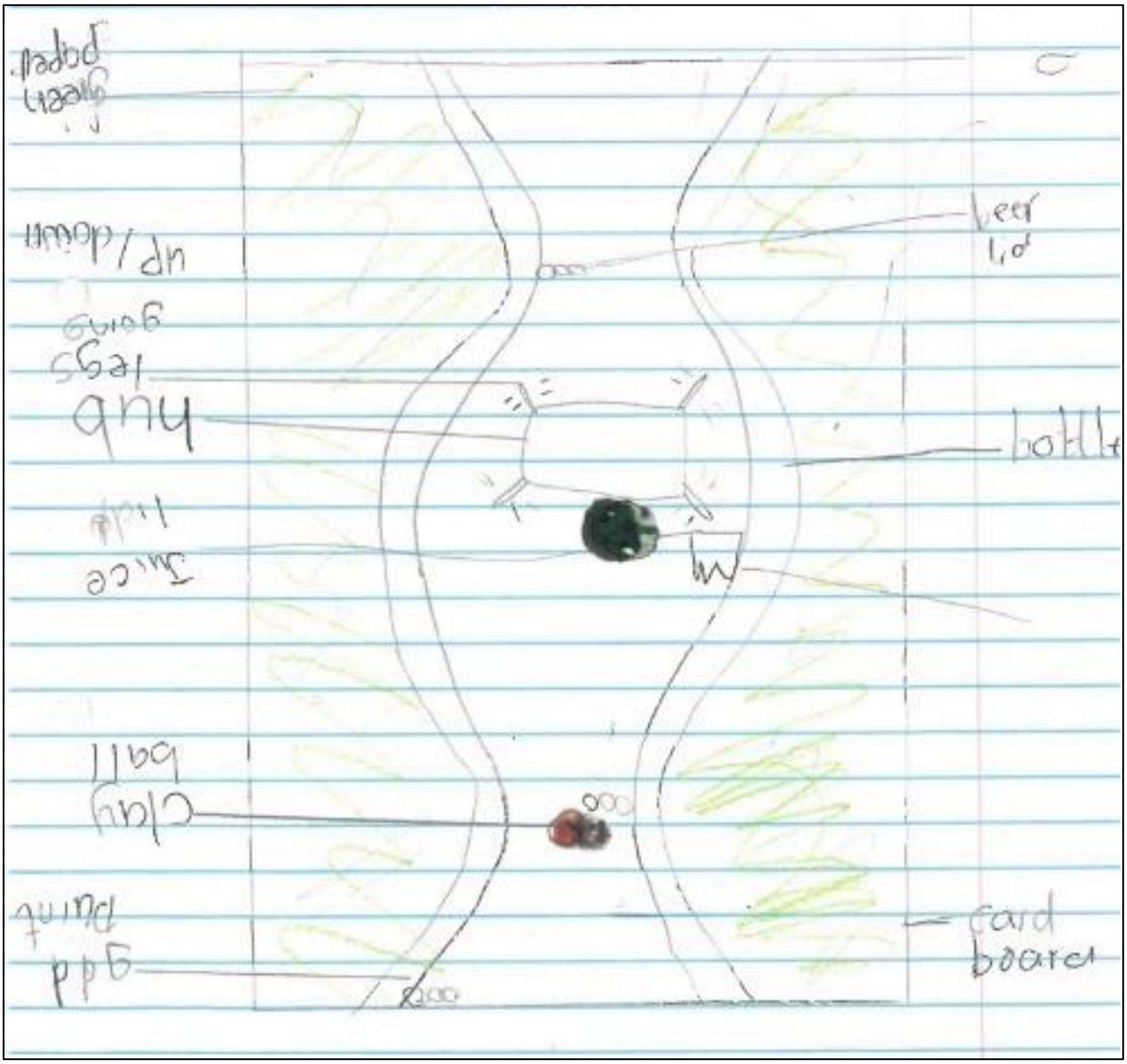


Photo evidence 39

Miniature golf course design



Learners effectively applied planning strategies to ensure that their designs were both functional and environmentally friendly. Through hands-on activities, they demonstrated practical competencies (quadrant B) in constructing prototypes and experimenting with different design elements.

Applying effective planning strategies and sustainable design principles

Throughout the development of this learning opportunity, learners applied effective planning strategies and sustainable design principles to their projects. They carefully considered the environmental impact of their designs and made conscious decisions to minimise waste and maximise resource efficiency. By doing so, learners demonstrated a strong commitment to sustainability and innovation, showcasing their ability to think critically (quadrant A) about complex design challenges.

Collaborating with peers

Collaboration was a key aspect of the lesson, with learners actively engaging with their peers to share ideas, provide feedback and refine design concepts. This collaborative effort created a dynamic and creative learning environment, where learners felt comfortable exploring new ideas and taking risks. By working together, learners developed important relational competencies (quadrant C), such as communication and teamwork, which are essential for success in a collaborative work setting.

Presenting the final design concept

At the conclusion of the lesson, learners presented their final design concepts to the class, highlighting their thought processes, planning strategies and innovative design elements. They reflected on the importance of sustainability in design, articulating how their projects met specified requirements and demonstrated creative solutions to real world problems. The presentations showcased the learners' ability to communicate effectively and think critically about design challenges, underscoring the success of the lesson in developing their design competencies and fostering a deeper understanding of sustainability in design. These final designs can be seen in Photo evidence 29.

5.3.12.4 Reflecting on transformation

Cycle 12 represented a pivotal stage in the learners' design and coding journey, as they honed their competencies in planning and designing. The project tasked them with creating either a miniature golf course or a simulated pet, using recyclable materials and LEGO® pieces. This challenge not only required technical proficiency but also encouraged learners to develop a sense of confidence in their abilities. Through thoughtful reflection, it became evident that learners were not just tackling the technical aspects of design and coding but also building resilience. They embraced challenges and setbacks as opportunities for personal growth, fostering a mindset that welcomed new challenges.

One of the key outcomes of this cycle was the significant improvement in the learners' understanding of design principles. By applying these principles practically, they were able to make abstract concepts more tangible and comprehensible. As an educator, my goal was to provide learners with ample opportunities for enhancement and refinement, aiming to cultivate a sense of achievement and mastery in their design endeavours. The process of reflection played a crucial role in guiding learners towards higher levels of proficiency and ingenuity in their projects.

Throughout the cycle, continuous assessments and feedback were used to help learners improve not only their miniature golf courses or pets but also their problem-solving abilities and creative thinking competencies. The reflection step at the end of the cycle allowed for individual and group reflections on the planning process. Discussions revolved around the challenges faced, successful strategies employed and an analysis of how Whole Brain® thinking contributed to effective planning. This holistic approach to learning not only enhanced the learners' technical competencies but also nurtured their ability to think critically and creatively, preparing them for future challenges in the field of design and coding.

5.3.13 Cycle 13: Coding and robotics integration (2 weeks)

5.3.13.1 Planning for transformation

At this point of the project, the action research redirects its attention towards the incorporation of coding and robotics into the project.

The learning opportunities included:

- Constructing a mini golf course (also known as putt-putt) or mini pet using recyclable materials, incorporating LEGO® pieces into the design
- Creating a programming code for the hub that controls the movement and interactions of their mini golf course or pet

5.3.13.2 Acting to transform

Constructing a mini golf course or mini pet using recyclable materials, incorporating LEGO® pieces into the design

The aim of this project was to construct a mini golf course or mini pet using recyclable materials and incorporating LEGO® pieces into the design. This initiative not only aimed to create a fun and engaging activity but also promoted environmental sustainability and catered to various thinking preferences as outlined by the HBDI®. By using recyclable materials, the project was aligned with individuals who prefer practical and realistic solutions (A quadrant), as it demonstrated a tangible way to repurpose waste. Incorporating LEGO® pieces appealed to those who favour sequential and organised approaches (B quadrant), as it allows for structured planning and construction. The creative aspect of designing the course or pet catered to individuals who prefer holistic and intuitive thinking (C quadrant), offering the freedom to experiment with different configurations. Additionally, the interactive nature of the mini course or pet engaged individuals who value interpersonal relationships and collaboration (D quadrant), as it encouraged teamwork and communication.

Creating a programming code for the hub that controls the movement and interactions of their mini golf course or pet

The aim of creating a programming code for the hub that controls the movement and interactions of a mini golf course or pet is also aligned with the principles of the HBDI®. Individuals with different thinking preferences, as identified by the HBDI®, can benefit from this project. For those who prefer practical and realistic solutions (A quadrant), the code allows for the precise control of movements and interactions, translating ideas into tangible actions. Individuals who favour sequential and organised approaches (B quadrant) can appreciate the structured nature of coding, where each line of code builds upon the previous one to create a coherent program. The creative aspect of coding appeals to those who prefer holistic and intuitive thinking (C quadrant), as it allows for experimentation and the creation of unique behaviours for the mini course or pet. Individuals who value interpersonal relationships and collaboration (D quadrant) can benefit from the collaborative aspect of coding, where ideas can be shared and refined to improve the overall project.

5.3.13.3 Observing the transformation

Constructing a mini golf course or mini pet using recyclable materials, incorporating LEGO® pieces into the design

During the observed lesson, learners were actively engaged in designing and building their projects. They worked collaboratively in pairs or small groups, using a variety of recyclable materials and LEGO® pieces to construct their mini golf courses or mini pets. The educator provided guidance, encouraging creativity and problem-solving competencies among the learners.

The creative aspect of coding appealed to those who preferred holistic and intuitive thinking (C quadrant), as it allowed for experimentation and the creation of unique behaviours for the mini course or pet. Individuals who valued interpersonal relationships and collaboration (D quadrant) benefited from the collaborative aspect of coding, where ideas could be shared and refined to improve the overall project.

One notable challenge faced by the educator was ensuring a balance between creative exploration and adherence to coding principles. This challenge was particularly evident in addressing varying levels of coding proficiency among learners and fostering an inclusive coding environment. Learners encountered obstacles in grasping complex coding constructs, especially when moving from introductory to more advanced coding tasks. The potential for frustration during coding challenges and the need for individualised support were additional learner specific obstacles.

An advantage was that learners were actively engaged in designing and then building their projects. Photo evidence 40 to 44 depict learners building their designs. Photo evidence 40 portrays an interior environment where a learner is engaged in work at a table. The table is adorned with an assortment of objects, such as a pair of scissors with orange handles, a cutting mat in green, a see-through pouch filled with a variety of coloured markers, sheets of white paper embellished with handwritten text or drawings, a metallic tray being held by the individual and a cardboard box adorned with printed labels and instructions. The items present on the table indicate that the learner is involved in crafting their miniature golf course, requiring meticulous cutting or assembling tasks.

Photo evidence 40

Group 1 building miniature golf course

Photo evidence 41 portrays a table that is filled with a multitude of different objects in a disorganised manner, like a prominently displayed Kellogg's Cornflakes box, featuring a conspicuous cut out section. Multiple additional boxes and packaging materials are scattered around. Amidst the clutter, there are two plastic bottles; one green and the other clear. The table is adorned with a multitude of coloured markers. Two learners' arms are visible; one appears to be engaged in the act of writing or drawing on paper, while the other is holding an electronic device. These learners are busy building their pet.

Photo evidence 41

Group 2 building a pet

Photo evidence 42 exhibits a disorganised table adorned with a multitude of diverse objects. A crimson pencil case containing an assortment of pencils, markers and scissors is observable. There are two plastic bottles and a piece of paper containing handwritten text and diagrams. A learner's limb is partially discernible in the upper right corner of the image. The co-existence of scissors, papers and markers implies an atmosphere conducive to crafting or educational activities. The placement of these objects alongside food containers emphasises a relaxed and energetic environment. The image represents a dynamic and productive atmosphere where learners are building their pet.

Photo evidence 42

Group 3 building a pet

Photo evidence 43 depicts learners engaged in the task of manipulating a sizable cardboard box on a wooden table. The cardboard box has perforations on its sides. An individual is positioning a tool, resembling a straight edge, in contact with the box. A separate individual's hand is discernible, firmly grasping another section of the box, seemingly engaged in the act of inscribing upon it. Various papers, including written texts and illustrations containing designs, can be seen on the table. There is a visible pouch on the table that contains coloured pencils. The image depicts an interactive activity that involves creating their pet.

Photo evidence 43

Group 4 building a miniature golf course

Photo evidence 44 depicts two learners actively participating in the practical activity of building a small-scale golf course. The image depicts a collaborative endeavour in which materials such as cardboard, a ruler and various other items are being employed to construct the structure. The learners' engagement demonstrates a learning environment that encourages interactivity and promotes the development of creativity and practical competencies.

Photo evidence 44

Group 5 building a miniature golf course

Creating a programming code for the hub that controls the movement and interactions of their mini golf course or pet

After completing the construction learning opportunities, learners proceeded to create a programming code for the hub to control the movement and interactions of their mini golf course or pet. They used block-based coding languages to program the hub's actions, including movement, sound and sensor interactions. Learners demonstrated a good understanding of basic programming concepts, such as loops, conditions and events to achieve the desired behaviours of their projects. Throughout this process, Whole Brain® thinking was evident, with learners displaying analytical competencies in breaking down coding tasks, an experimental mindset in trying out different approaches, practical thinking in applying theoretical knowledge and collaborative efforts in working together to troubleshoot and refine their code.

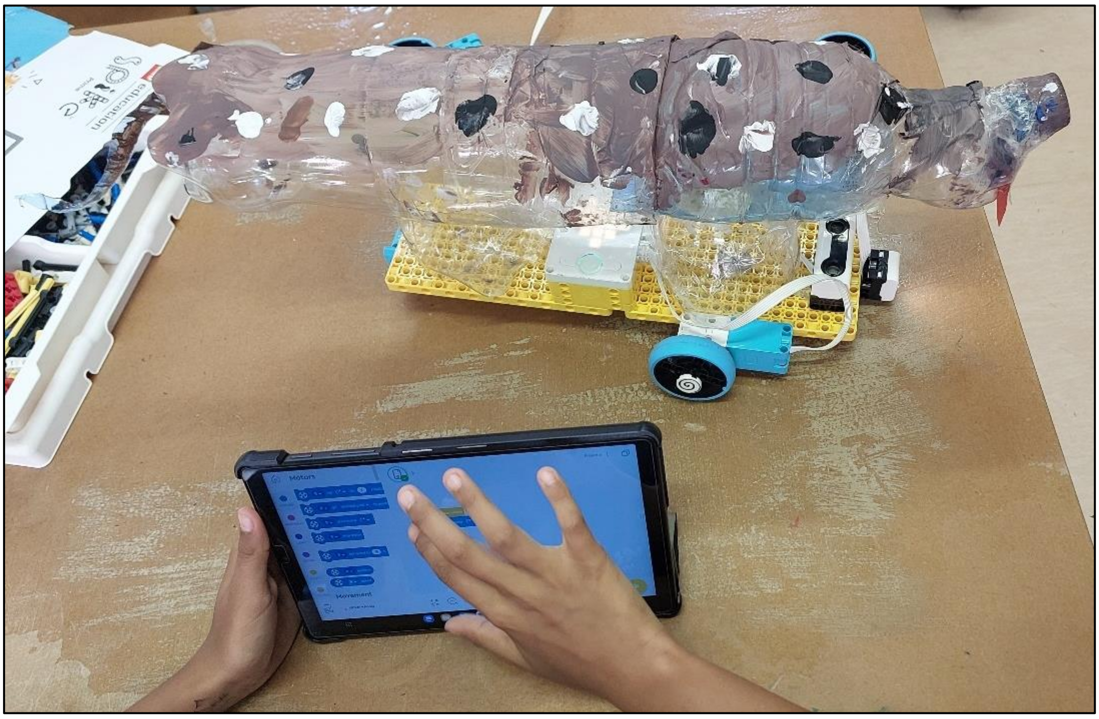
5.3.13.4 Reflecting on transformation

Upon careful reflection, it is clear that learners were experiencing a process of acquiring competencies and knowledge in coding, which encompassed not only the mastery of coding techniques but also the adoption of the creative opportunities that coding presented.

Photo evidence 45 captures a learner engaging with a tablet that showcases an interface specifically designed for programming a robotic dog. Next to the learner, there is a rudimentary replica of a robot made from reused materials and electronic parts that can be seen. The robot seems to be a combination of plastic bottles embellished with black markings, mounted on a chassis equipped with wheels. The image depicts an indoor environment where educational activities are being conducted. The learners' engagement signifies a learning environment that encourages interactivity and facilitates the growth of creativity and practical competencies.

Photo evidence 45

Group 4 creating programming code for their pet



Based on the Photo evidence 46, it can be observed that a learner is fixing the hub to their miniature golf course. The learner is holding the hub with both hands and appears to be using a screwdriver to attach it to the golf course.

Photo evidence 46

Group 5 incorporating the hub into their project

The challenges encountered In this learning opportunity, such as differing levels of coding expertise, presented valuable opportunities for learning. The integration of coding and robotics necessitated a careful equilibrium between providing structured guidance and cultivating an environment conducive to individual exploration.

My objective in this learning opportunity was to promote a learning experience that not only improved coding competencies but also fostered a mindset of creativity and innovation among learners. The iterative nature of the action research process was reiterated, as learners consistently improved their coding practices. The process of reflection was crucial in influencing future learning opportunities, guaranteeing that learners not only achieved proficiency in coding but also developed the necessary creative mindset to tackle future challenges.

5.3.14 Cycle 14: Testing, iteration, and presentation (2 weeks)

5.3.14.1 Planning for transformation

During the last step, the emphasis is placed on testing, iteration and presentation abilities. Learning opportunities are established during the planning step, along with the creation of guidelines for the testing and iteration process. Additionally, presentation practice sessions are scheduled. The learning opportunities were as follows:

- Testing their mini golf course or mini pet to ensure it functions as intended, identifying any issues and iteratively improving their design
- Using feedback from testing to iteratively improve their mini golf course or mini pet, incorporating new ideas and addressing any identified shortcomings
- Presenting their mini golf course or mini pet, explaining their design choices, coding logic and the functionality of their project to their peers
- Reflecting on the testing and iteration process, identifying challenges faced and strategies employed to overcome them; promoting a deeper understanding of the design and coding principles involved

5.3.14.2 Acting to transform

Testing their mini golf course or mini pet to ensure it functions as intended, identifying any issues and iteratively improving their design

In the final moments of the project, learners were tasked with testing their mini golf course or mini pet to ensure it functioned as intended. This involved identifying any issues and iteratively improving their design based on the results of their tests. The practical application of their project appealed to those who preferred a holistic and intuitive approach (C quadrant) as they actively tested their creation to ensure its correct functionality. By identifying any issues during testing, learners could then make improvements to enhance the functionality of their mini golf course or mini pet. The iterative nature of this process encouraged learners to continually refine their design, improving their problem-solving competencies and attention to detail, aspects favoured by those who prefer analytical thinking (A quadrant).

Using feedback from testing to iteratively improve their mini golf course or mini pet; incorporating new ideas and addressing any identified shortcomings

Learners used feedback from testing to further improve their projects, incorporating new ideas and addressing any identified shortcomings. This aim highlighted the importance of using feedback as a tool for improvement, appealing to those who value interpersonal relationships and collaboration (D quadrant). By incorporating feedback from testing, learners refined their designs, incorporating new ideas and addressing any identified shortcomings. This iterative approach to improvement encouraged learners to think critically about their work and consider alternative solutions, fostering creativity and resilience in the face of challenges.

Presenting their mini golf course or mini pet, explaining their design choices, coding logic and the functionality of their project to their peers

Learners were required to present their mini golf course or mini pet to their peers, explaining their design choices, coding logic and the functionality of their project. This presentation not only allowed learners to showcase their work but also enhanced their communication and presentation competencies; competencies valued by those who prefer a structured and sequential approach (B quadrant). It provided an opportunity for learners to articulate their ideas clearly and receive feedback from their peers, further enriching their learning experience.

Reflecting on the testing and iteration process, identifying challenges faced and strategies employed to overcome them, promoting a deeper understanding of the design and coding principles involved

Learners reflected on the testing and iteration process, identifying challenges faced and strategies employed to overcome them. This reflective practice promoted a deeper understanding of the design and coding principles involved in their project, appealing to those who value holistic and intuitive thinking (C quadrant). By reflecting on the challenges they faced during testing and iteration, learners identified strategies that were effective in overcoming these challenges, gaining insight into their own problem-solving competencies and learning from their experiences. This reflective practice helped learners develop a more nuanced understanding of the design and coding principles underlying their project, enhancing their overall learning experience.

5.3.14.3 Observing the transformation

Testing and iterative improvement

During this learning opportunity, learners with a preference for practical application (C quadrant) were particularly engaged in testing their mini golf courses or mini pets to ensure they functioned as intended. They applied their coding and problem-solving competencies, demonstrating a practical understanding of design and coding principles. Learners who favoured analytical thinking (A quadrant) excelled in identifying issues and iteratively improving their designs. Challenges for the educator included facilitating effective testing sessions and guiding learners in the iterative improvement process, requiring a balance between addressing the detailed needs of analytical thinkers and ensuring the practical application for those favouring holistic thinking (D quadrant).

Incorporating feedback

Following testing, learners used feedback to further enhance their projects. Those

inclined towards practical application (C quadrant) demonstrated a willingness to incorporate new ideas and address shortcomings, showing a flexible and iterative approach to design. This section of the project encouraged learners to think critically about their work and consider alternative solutions; aspects favoured by those who prefer analytical thinking (A quadrant). Challenges for the educator included ensuring a seamless integration of individual project modifications within group presentations, requiring a balance between addressing the detailed needs of analytical thinkers and ensuring practical application for those favouring holistic thinking (D quadrant).

Presentation competencies

This presentation task particularly appealed to learners with a preference for interpersonal relationships and collaboration (D quadrant), as it provided a platform for sharing ideas and receiving feedback. It also allowed them to refine their communication competencies, an aspect favoured by those who prefer practical application (C quadrant). However, learners who favour analytical thinking (A quadrant) may have found the presentation aspect challenging, especially in managing time constraints and ensuring a comprehensive explanation of their design and coding logic.

Reflection and deeper understanding

Learners who favour practical application (C quadrant) may have found the reflection process particularly beneficial, as it allowed them to assess the real-world impact of their problem-solving strategies. Those inclined towards analytical thinking (A quadrant) likely appreciated the opportunity to analyse their approaches and refine their methods for future projects. However, learners encountered obstacles related to the potential for apprehension or nervousness during presentations, grappling with feedback and managing group dynamics during testing and iteration, highlighting the need for a balanced approach to accommodate different learning preferences.

Overall observations

Overall, the lesson exhibited a dynamic and engaging environment where learners actively participated in testing, iterating, presenting and reflecting on their mini golf courses or mini pets. Learners demonstrated a strong commitment to the practical application of their projects, with those favouring practical application (C quadrant) and analytical thinking (A quadrant) showcasing particular strengths in testing, iteration and incorporating feedback. However, challenges arose in managing group dynamics, particularly related to learners' varying comfort levels in presenting and grappling with feedback. Some learners exhibited behaviours such as dropping sets, not cleaning up and reluctance to transition from building to coding, indicating a need for clearer guidelines and expectations regarding classroom etiquette and transitions between activities. Despite these challenges, the lesson effectively fostered collaboration, critical thinking and problem-solving competencies, enhancing learners' understanding of design and coding principles.

5.3.14.4 Reflecting on transformation

Upon reflection, it becomes evident that learners were not solely improving the technical aspects of their projects, but also sharpening vital competencies in communication and presentation. The testing and iteration process offered them a practical setting to employ their problem-solving abilities, while the presentation aspect fostered their proficiency in effectively expressing their ideas. Diverse interpretations of the project were evident among learners, with some groups conceptualising the hub as a figurative entity engaged in the act of positioning (as seen in Photo evidence 47), while others incorporated the hub as an obstacle within their designs (as seen in Photo evidence 48 and 49).

From Photo evidence 47, it is evident that a handcrafted miniature golf course is positioned on a light-coloured surface. The course is distinguished by its unique structural and chromatic attributes. The object seems to be meticulously made by hand, featuring a blue portion that resembles a constructed edifice attached to a brown foundation, likely symbolising the earth or surroundings. Next to this building is a verdant level area with numerous openings, suggesting the location of the miniature golf course's playing field. The hub is positioned underneath the course. The intricate design implies that when the ball enters any of these cavities, it activates a mechanism within the central part that generates sound.

Photo evidence 47

Group 6 final project

Based on Photo evidence 48, it can be observed that there is a handmade miniature golf course with a hub placed on top of the course. It appears to be handcrafted, with a green section that resembles a building structure affixed to a green base, which is presumably meant to represent the ground or landscape. Adjacent to this structure is a green flat surface with multiple holes, indicative of the playing field of the miniature golf course. The hub is used to put the ball into the hole to score a point.

Photo evidence 48

Group 1 final project

The challenges faced, such as nervousness during presentations, emphasised the significance of addressing not only technical expertise but also the interpersonal competencies necessary for comprehensive growth.

Photo evidence 49 shows a handmade miniature golf course where the hub is used as a spinning obstacle to prevent the ball from entering the hole. The model is placed on a wooden surface and appears to be made of cardboard. The base of the model is painted green with blue walls affixed at various points to form obstacles.

Photo evidence 49

Group 7 final project

Certain groups opted for an alternative approach by conceptualising and constructing robotic pets. Notably, one such pet is fashioned with the hub serving as a central "heart," imbued with capabilities to produce simulated beating sounds and animalistic vocalisations exemplified in Photo evidence 29. Meanwhile, another variant of the robotic pet, exemplified in Photo evidence 30, is characterised by the incorporation of wheels, endowing it with the capacity for locomotion. This diversification in design choices among groups exemplifies the creative latitude afforded within the learning context, wherein learners adeptly transpose theoretical knowledge into inventive applications, fostering a multifaceted exploration of robotic functionalities.

In Photo evidence 50, there is a creative representation of a pet constructed from recyclable materials. The body is made from a cardboard box with drawn features to resemble an animal, and the head consists of a red plastic container adorned with bottle caps to mimic eyes and nose. The cardboard has drawings that outline the shape of ears and legs, giving it an animal like appearance. There's cursive writing on the cardboard, though it is not entirely clear what it says due to the angle and quality of the image. Three bottle caps are attached to the red container representing two eyes and a nose; two are blue and one is red. The entire assembly is placed on another piece of flat cardboard

Photo evidence 50

Group 3 final project

In Photo evidence 51, a makeshift pet constructed from recyclable materials is observed. The body of the pet is crafted from a cylindrical object, possibly a used bottle or canister, adorned with various patterns and designs to simulate the appearance of an animal's fur or skin. The pet is mounted on a platform made of LEGO® pieces equipped with wheels to facilitate mobility.

Photo evidence 51

Group 4 final project

My objective during this learning opportunity was to direct learners towards a level of expertise where they could competently evaluate, refine and showcase their projects. The iterative nature of the action research process played a crucial role in cultivating a culture of ongoing enhancement. The process of reflection was essential in improving learning opportunities, guaranteeing that learners not only achieved excellence in technical aspects but also cultivated the indispensable communication and presentation competencies necessary for future success.

5.4 Conclusion

This chapter has undertaken a comprehensive examination of the action research cycles that extended over three terms, revealing a process of significant change in the field of coding and robotics education. It goes beyond the usual way of gaining knowledge, sparking a strong desire to explore and fostering a dedication to continuous learning in the quest for educational greatness.

As educators, we have a duty that goes beyond the boundaries of conventional classrooms. This study involved the creation of an environment that fully embraces the Whole Brain® construct, which is fundamental to the action research cycles undertaken. These cycles represented a committed endeavour to understand, alter and introduce innovative constructs within the ever-changing field of coding and robotics education. This chapter aimed to present a thorough overview of the notable progress made during this research, carefully analysing the distinct obstacles and achievements experienced throughout each cycle.

The iterative process of action research forms the foundation of this transformative endeavour. Every term consists of strategic cycles, starting with careful planning and ending with reflective steps after going through implementation. This narrative is skilfully integrated into the essence of each term, providing a detailed examination of Whole Brain® coding and robotics curriculum development. The comprehensive analysis not only clarifies the path taken, but also serves as a guiding light for educators and researchers exploring innovative educational approaches.

6. CHAPTER 6: DECODING EDUCATIONAL LABYRINTH THROUGH ANALYSIS OF THE WHOLE BRAIN® CODING AND ROBOTICS CURRICULUM

6.1 Introduction

"Education is the passport to the future, for tomorrow belongs to those who prepare for it today." Malcolm X (University of Pacific, 2022)

This chapter explores the essence of Malcolm X's profound words, focusing on my educational journey and examining the complex process of data analysis in the field of Whole Brain® coding and robotics. As I analyse a wide range of information gathered from various sources and methods, my goal is not just to interpret data but to extract meaningful insights that provide clarity and guidance. In this chapter, I explore the intricate data to reveal concealed patterns, emerging themes and transformative subtleties.

6.2 Introduction to the educational odyssey

In the journey through educational innovation, section 6.2 delves into the challenges and opportunities encountered during the development and implementation of a Whole Brain® coding and robotics curriculum tailored for Grade 4 learners.

6.2.1 Challenges and opportunities in developing a Whole Brain® coding and robotics curriculum for Grade 4

This section provides an examination of the challenges and opportunities faced during the execution of a Whole Brain® coding and robotics curriculum for Grade 4 learners. The challenges included the lack of tablets, which required the educator to manually code, the presence of large class sizes due to delayed delivery of equipment, and inadequate collaboration among learners who prioritised task completion over exploratory learning, visualising real world situations, constructing fundamental frameworks and understanding the implementation of sensors. Notwithstanding these difficulties, there was a noticeable display of optimistic enthusiasm and keenness among learners, particularly in effectively interacting with the technological aspects and demonstrating a curiosity in exploring the capabilities of the sets.

6.2.1.1 Challenges and opportunities identified through observing learning opportunities and educator's reflections

The challenges identified in observations of learning opportunities included a scarcity of tablets for coding, an insufficient quantity of sets and external factors such as load shedding that impacted the Wi Fi connectivity. In contrast, the successful completion of assigned tasks by all groups revealed opportunities to demonstrate creativity and coding competencies. The data analysis underscores the importance of tackling issues related to technology accessibility and group constraints, while also shedding light on possibilities for enhancing resource distribution and infrastructure assistance.

Additional difficulties arose in the availability of technology, the dynamics within groups and spatial limitations during observations of learning opportunities. However, this also presented opportunities for active engagement, collaboration and the resolution of conflicts within the groups. The analysis highlights the possibility of improving the allocation of resources and strategies for resolving conflicts to effectively tackle these challenges.

Other obstacles encompassed learners departing prematurely for extracurricular pursuits, dependence on the educator's computer for coding, hesitancy among certain learners to engage in independent experimentation, and the constraint of time within the one-hour time frame. Notwithstanding these difficulties, smaller groups presented opportunities because of extracurricular activities, demonstrations of Whole Brain® thinking and diverse thinking styles among learners. The overall conclusion indicated that there is a requirement to improve time management strategies, promote independent experimentation and acknowledge the Whole Brain® thinking approach in order to accommodate the diverse cognitive styles of learners.

Furthermore, I observed some practical challenges regarding the LEGO® Spike Prime™ sets. These challenges included hub's scratching, wheels developing flat spots impeding movement, and sets accumulating dirt from floor testing. These practical challenges highlighted the need for robust material design to withstand regular use and testing.

Additionally, I observed that learners were hesitant to explore, became more reliant on me after the holiday break, encountered difficulties with coding and aligning motors while building and faced comprehension issues when adapting the robot. The analysis highlights the importance of promoting self-directed exploration, addressing the period of readjustment after holidays and offering practical assistance and explicit guidance to foster learner independence and understanding.

6.2.1.2 Challenges and opportunities identified through learner interviews

An important obstacle, expressed honestly by a learner, concerned the interpersonal interactions within teams. The learner's statement, "Our teammates keep on saying they want to build, and they want to fight us," serves as evidence of the intricate intricacies of cooperation and communication in an educational setting. This challenge highlights the significance of improving collaborative strategies, advocating for efficient communication and fostering a collective sense of purpose among learners.

Additional factors influencing the learning environment were brought to attention when a fellow learner revealed, "A girl in our class dropped the whole box of Lego." This unforeseen disturbance highlights the difficulties that educators' face, which are beyond their immediate control. It underscores the importance of adaptability and perseverance in curriculum planning. This prompts a reassessment of contingency plans and strategies to mitigate unforeseen events that may hinder the smooth implementation of the curriculum.

Simultaneously, during the challenges, opportunities for improvement and enhancement emerge. The learner's request for greater autonomy, as stated by the phrase "Let our work be by ourselves," indicates a chance to encourage independent exploration. Enabling learners to assume responsibility for their learning journey is in line with the curriculum's primary objective of fostering not only coding and robotics proficiency, but also a sense of independent inquiry and problem-solving aptitude.

The interviews revealed additional insights into the learners' expectations, as indicated by responses such as "Coding" and "Building," which demonstrate a strong desire to acquire specific competencies. These revelations are crucial for customising the curriculum to match the learners' aspirations, thus guaranteeing its relevance and impact. The learner's statement, "These competencies are crucial as they enable us to construct and manipulate mechanical objects," emphasises the practical and tangible value of the competencies emphasised in the curriculum.

6.2.1.3 Combined insights

The challenges and opportunities identified through learner interviews and observations of learning opportunities, offer a detailed comprehension of the complexities involved in implementing a Whole Brain® coding and robotics curriculum. These insights collectively aid in the advancement of focused enhancements in teaching techniques, collaborative endeavours and infrastructure assistance. To tackle challenges effectively, it is necessary to adopt a comprehensive approach that includes technological advancements, strategic allocation of resources, conflict resolution tactics and a strong emphasis on durable material design. At the same time, the identified opportunities highlight the ability of learners to adapt and be creative, providing valuable insights for improving methods of facilitating learning and support systems. This integrated strategy guarantees a comprehensive and learner focused development of the curriculum, in accordance with the varied requirements and ambitions of Grade 4 learners.

6.3 Theoretical framework and methodological approaches

This section explores the complex connection between theoretical knowledge and practical application within the framework of a Grade 4 Whole Brain® coding and robotics curriculum.

6.3.1 The intersection of theoretical knowledge and practical application

Theoretical knowledge, which involves a careful focus on providing step by step instructions for building structures with LEGO® blocks, creates a learning environment that encourages analytical thinking through the logical arrangement of instructions and careful attention to detail. The theoretical basis is enhanced by a practical component, in which learners actively manipulate technological components. In this curriculum, there is a deliberate emphasis on promoting practical problem-solving competencies through the exploration of various techniques for activating the hub. The smooth incorporation of these components enhances a comprehensive and balanced educational environment for Grade 4 learners.

Theoretical knowledge prioritises problem definition, utilisation of sensors and storytelling. This theoretical knowledge is practically applied by breaking down problems into intricate details. By organising and connecting sounds with colours, learners actively participate in the practical implementation of problem-solving constructs. Visual aids are used strategically in this process to emphasise the commitment to facilitate a comprehensive learning experience that goes beyond theory.

Theoretical knowledge is built by exploring the understanding of prototypes and their significance. Learners often struggle to distinguish between prototypes and final products. Within the realm of practical application, learners adeptly produce numerous prototypes. Nevertheless, they face difficulties in rationalising the choice of the most suitable prototype. This dual observation highlights the necessity for theoretical clarification and guidance in the practical implementation, suggesting a possible domain for focused intervention and assistance.

Going forward, the assessment of grabber designs takes centre stage in theoretical knowledge, as learners demonstrate their comprehension of the purpose and standards for evaluation. Learners effectively apply theoretical knowledge by performing testing procedures and gathering data. Nevertheless, difficulties arise in ensuring uniformity throughout the testing process and effectively expressing observations. The challenges observed in practical situations indicate the need for extra assistance and guidance to ensure a more efficient implementation of experimental procedures.

A consistent pattern arises when evaluating grabber designs, with an emphasis on observations, test size and weight as key components of theoretical knowledge. During the practical application, learners actively participate in testing grabber designs. However, they face persistent difficulties in clearly expressing their observations and justifications. This restatement emphasises the importance of ongoing support in maintaining consistent experiments and improving argumentation competencies, which contributes to an iterative and adaptable educational approach.

Evaluating current structures and components is essential for applying theoretical knowledge and developing critical thinking abilities. The practical application entails promoting innovative thinking throughout the process of modifying and creating code. Difficulties arise in expressing observations and justifications, indicating the need for further assistance in communication competencies and a stronger connection between theoretical knowledge and practical application.

Theoretical knowledge introduces Whole Brain® thinking strategies, emphasising the significance of organisation and efficient packing. The practical application entails learners participating in discussions regarding the difficulties encountered in locating LEGO® pieces, while actively promoting innovative thinking to maximise the utilisation of storage containers. The successful combination of theoretical knowledge and practical application demonstrates the effectiveness of the educational approach and encourages problem-solving in real world situations using both analytical and creative thinking, thus preparing learners for a comprehensive understanding of the subject matter.

The application highlights the significance of loops and logical thinking in coding geometric shapes, further emphasising the importance of Whole Brain® thinking in theoretical knowledge. Learners effectively applied loop structures in practical situations but faced difficulties in accurately aligning their movements to create specific shapes. This comparison emphasises the successful combination of theoretical understanding and practical implementation, with the identified difficulties serving as indicators that need to be addressed in future versions of the curriculum.

To summarise, the examination of the intricate interaction between theoretical knowledge and practical implementation in Grade 4 Whole Brain® coding and robotics education uncovers a complicated yet mutually beneficial relationship. The smooth incorporation of these components acts as a fundamental principle of teaching, producing a fully engaging and efficient learning encounter. The identified challenges serve as important indicators, pointing out specific areas that need constant improvement and enhancement in learning opportunities and support systems, ultimately contributing to the continuous development of the curriculum.

6.4 Identifying pre-existing conditions for implementing action research-DRIVEN Whole Brain® coding and robotics curriculum

This section offers an extensive exploration of the pre-existing conditions identified through meticulous analysis of the learning opportunities “Observation Form” data (Appendix J) in the context of implementing the Whole Brain® coding and robotics curriculum for Grade 4 learners.

6.4.1 Examining prerequisites for effective integration

This section provides a thorough examination of the pre-existing conditions that were identified through the analysis of data from the learning opportunities, observation form and educator reflections. These conditions were considered in relation to the implementation of the Whole Brain® coding and robotics curriculum. The presence of tablets, delivery issues with new sets and the subsequent restrictions on group size created significant pre-existing challenges for implementation. Moreover, the challenges were exacerbated by the complexities involved in building fundamental structures and comprehending sensors. The analysis underscores the critical necessity of effectively implementing strategies to tackle challenges associated with technology accessibility, group interactions and varied learning preferences.

The first pre-existing condition pertains to reliance on the educator's computer for coding. The conclusion emphasised the necessity of time management, and technology accessibility to achieve effective curriculum implementation. In these time-limited sessions, the reliance on a single educator's computer for coding activities became more apparent. This reliance potentially hindered the collaborative and hands-on coding experiences that are crucial for a comprehensive understanding of the subject matter. This analysis highlighted the significance of improving support systems and technological availability to enhance the overall educational experience for Grade 4 learners.

A category of pre-existing conditions pertains to difficulties associated with tablet and set restrictions which are worsened by power outages, affecting Wi-Fi and hub updates. Tablet and set restrictions in an educational context pertain to limitations and constraints placed on the use and functionalities of tablets and related equipment which can pose challenges. These restrictions impose constraints on the ability to use certain applications, features or functionalities of the tablets and related devices, thereby impeding the smooth incorporation of these technological tools into the curriculum. These challenges worsened when power outages impacted Wi-Fi and hub updates. Power outages hinder the accessibility of electricity, which is essential for sustaining the operation of electronic devices, such as tablets. Wi-Fi connectivity is crucial in the field of educational technology as it enables access to online resources, collaborative platforms and necessary updates for the smooth operation of educational centres. Updates to the hub are essential to ensure that educational content remains up to date, pertinent and in line with the curriculum. The convergence of tablet usage and imposed limitations, coupled with power interruptions impacting Wi-Fi connectivity and hub software updates, engenders a heightened level of intricacy and difficulty. Learners encountered challenges when trying to access educational resources and engage in online activities. The conclusion restates the importance of addressing challenges related to technology availability and infrastructure support to successfully implement the curriculum. This analysis highlighted the significance of acknowledging and addressing obstacles associated with technological limitations and external factors impacting infrastructure.

Group conflicts, exacerbated by constraints arising from tablet and set limitations, constitute supplementary pre-existing factors. Group conflicts refer to challenges related to group dynamics and interpersonal conflicts. These conflicts can manifest in various forms, such as disagreements over tasks, differences in opinion or challenges in working together effectively as a group. The issue of oversized groups, stemming from a scarcity of available Lego sets, has given rise to interpersonal conflicts among learners. The learners' comments indicated a strong inclination towards exerting control and asserting dominance over tasks, especially when it comes to coding and building. The team members' desire for authority and influence was apparent as they asserted their preference for specific roles, resulting in conflicts and confrontations. The learners portrayed a competitive environment characterised by teammates expressing a preference for construction, resulting in disagreements. The conclusion emphasises the imperative of tackling these circumstances by implementing solutions that encompass the availability of technology, limitations in resources and efficient conflict resolution within groups. This detailed analysis highlighted the complex and varied nature of the challenges, which requires a comprehensive approach to promote cooperative and harmonious learning environments.

Other pre-existing conditions encompass challenges related to time limitations caused by early learner departures and the learning opportunities being too short. The inherent challenge of early learner departures, compounded by the brevity of the learning opportunities, raises concerns about the equitable distribution of instructional time. Learners facing time constraints due to early departures find it challenging to fully engage with the curriculum content within the restricted time frame. The conclusion emphasises the necessity of time management, and technology accessibility in order to achieve effective curriculum implementation. This analysis highlights the significance of improving support systems and technological availability to enhance the overall educational experience for Grade 4 learners.

An essential initial stage in implementing the action research-driven Whole Brain® coding and robotics curriculum is the comprehensive examination of pre-existing conditions. It is crucial to address specific needs such as the availability of technology, limitations in resources, dynamics within the group and time constraints in order to successfully implement the curriculum. This understanding guides the creation of focused interventions and support systems to ensure the effectiveness and inclusiveness of the educational effort.

The analysis not only identified challenges but also acknowledged the strengths exhibited by learners. The individuals demonstrated notable strengths in their enthusiasm for practical experimentation and their ability to effectively communicate during discussions. Nevertheless, difficulties in ensuring uniformity throughout the testing process and expressing observations and justifications were recognised. The conclusion is that effective integration necessitates the cultivation of enthusiasm while also necessitating guidance in maintaining consistency and enhancing argumentation competencies. This sophisticated approach recognised the aptitudes of learners while pinpointing areas that require improvement for a more thorough learning experience.

Ultimately, the analysis of pre-existing conditions also uncovered increased reliance on the educator following the vacation period, along with difficulties in understanding and coordination during construction. This indicated a potential requirement for focused assistance to tackle these pre-existing conditions and guaranteed a more seamless reintegration into the curriculum. An in-depth examination of these conditions yielded valuable insights into the areas that necessitate targeted attention and intervention for the comprehensive success of the Whole Brain® coding and robotics curriculum.

6.4.2 Addressing the necessities for successful Implementation

This section provides a detailed analysis based on journal entries, documenting the positive aspects and difficulties encountered while implementing the Whole Brain® coding and robotics curriculum for Grade 4 learners. The comprehensive analysis seeks to offer valuable insights into the dynamics of the learning environment, with a focus on the necessary conditions for successful integration.

The initial journal entry reflection emphasised the strengths demonstrated by learners, including their enthusiastic collaboration and successful engagement with essential components such as operating the hub, controlling motors and utilising the force sensor. Furthermore, there was a notable inclination towards utilising the colour sensor. The challenges recognised are the initial difficulty in building fundamental structures and the complexity in comprehending the application of the distance sensor. The conclusion derived from this entry emphasises the significance of tackling obstacles in construction, comprehension and delivering personalised assistance as essential conditions for successful integration.

Building upon subsequent journal reflections, the strengths were expanded to include enthusiastic collaboration, teamwork and observed problem-solving competencies among learners. The level of successful interaction with technological components remained constant. Nevertheless, challenges progressed to encompass the initial challenge of formulating a practical and pertinent problem statement, as well as the intricacies involved in precisely calibrating the colour sensor. The conclusion highlighted the necessary conditions for successful integration, advocating for the promotion of collaboration, teamwork and the resolution of challenges in problem formulation and sensor calibration.

Through the display of interest and understanding in prototypes, as well as the ability to generate multiple prototypes effectively, learners' strengths were emphasised in an alternative evaluation. The challenges arose from the difficulty in rationalising the selection of the optimal prototype and the necessity for a distinct comprehension of the distinctions between prototypes and final products. The conclusion highlighted the necessary conditions for successful integration, emphasising the development of understanding, practical implementation and clarification of important ideas.

Furthermore, learners' enthusiasm for practical experimentation and their ability to effectively communicate during discussions serve as additional evidence of their strengths. Challenges encompass the arduous task of ensuring consistency throughout the testing process and effectively expressing observations and justifications. The conclusion highlights the necessary conditions for successful integration, which include promoting enthusiasm while acknowledging and addressing challenges through guidance to ensure coherence and enhance argumentation abilities.

The strengths that consistently emerged from various reflections included learners' enthusiasm, engagement, effective group support, collaborative discussions and the exchange of diverse thinking styles and organisational preferences. The challenges encompassed the difficulty of ensuring consistency throughout the testing process and effectively expressing observations and justifications. The collective findings of these entries emphasised the necessary conditions for successful integration, which include cooperative learning, transparent dialogues and the incorporation of various cognitive approaches, all of which contribute to fostering a constructive and all-encompassing learning atmosphere.

The final reflection discussed here highlights the presence of strengths, which are evident in learners' enthusiasm, active participation, effective collaboration and cooperation in tasks involving modifications. The conclusion restates the necessary conditions for successful integration, highlighting the importance of tackling obstacles through enthusiastic involvement, collaboration and teamwork. This reflective analysis of journal entries offered a detailed comprehension of the advantages and difficulties associated with the Whole Brain® coding and robotics curriculum. It served as a guide for future endeavours to enhance and perfect educational practices.

6.5 Understanding the components of an action research-DRIVEN Whole Brain® coding and robotics curriculum

This section embarks on a comprehensive exploration into the intricacies of an action research-driven Whole Brain® coding and robotics curriculum for Grade 4. Under the umbrella of understanding, the focus narrows down to delineating key components and outlining curriculum entailments, unravelling the critical foundations that shaped this innovative educational journey.

6.5.1 Defining key components in Whole Brain® coding and robotics education

This subsection delves into the analysis of important components obtained from the learning opportunities “Observation Form” data (Appendix J) in relation to the implementation of the Whole Brain® coding and robotics curriculum. It is crucial to clearly identify and define these essential components to establish a solid framework for educators, which will help guide the development and implementation of an effective curriculum.

The initial set of key components prioritises the utilisation of Whole Brain® thinking strategies and the systematic arrangement of code. Emphasis is placed on promoting critical and creative integration, adaptability, organisation, teamwork and cooperation. The analysis of the data revealed that the application of Whole Brain® thinking, sequential organisation and collaborative competencies were key components. This acknowledgment is essential for educators to learn to customise their learning opportunities, acknowledging the importance of cognitive involvement, organising coding techniques and promoting collaborative learning environments.

Emphasising discovery learning and guided learning modes is recognised as a crucial component going forward. The primary focus of learning opportunities is on constructing structures, utilising the central hub and sensors and participating in practical activities. The comprehensive approach incorporates diverse learning opportunities and practical activities, emphasising a holistic learning experience that integrates theoretical knowledge with real world application.

Constructivism, group work and experiential learning are acknowledged as instructional methods in another set of important components. The curriculum focuses on the identification of problems, the utilisation of sensors and the generation of narratives through coding. The combination of constructivism, collaborative learning and experiential learning results in a versatile instructional approach. The challenges associated with maintaining consistency during testing highlight the significance of providing clear instructions. This leads to the conclusion that key factors include collaborative learning, facilitation and an ongoing emphasis on improving the clarity of instructions.

The following collection of essential components includes collaborative work, hands-on learning and an emphasis on creating prototypes. The achievement of effectively involving learners in comprehending prototypes is a crucial factor, highlighting the importance of collaborative learning, practical experiences and a focus on comprehending and creating prototypes.

The recurring presence of fundamental components such as collaborative work, guidance and experiential learning, coupled with difficulties in ensuring uniformity during assessments, highlighted the continuous significance of these components. The conclusion highlighted the importance of collaborative learning and facilitation, along with the chance to improve instructional clarity to effectively tackle challenges.

From a broader standpoint, the curriculum implementation has highlighted the significance of practical experimentation in comprehending product performance. The challenges identified highlighted the necessity of providing explicit instructions and ongoing support throughout the learning process. The curriculum entails the incorporation of practical experimentation, explicit instructional guidance and a consistent support system to improve the overall learning experience.

In essence, the identification and definition of crucial components in the Whole Brain® coding and robotics curriculum made a substantial contribution to educational practices. Having a thorough comprehension of the subject matter allows educators to create and execute a curriculum that not only encourages active thinking and practical abilities, but also effectively tackles obstacles by providing explicit guidance and ongoing assistance.

6.5.2 Outlining curriculum entailments in Whole Brain® coding and robotics education

Building upon the defined key components, the subsequent subsection navigates the terrain of curriculum entailments. Here, the focus expands to critically analyse lessons learnt from the implementation of the Whole Brain® coding and robotics curriculum, outlining the curriculum entailments derived from these insights. By outlining these entailments I seek to provide a panoramic view of the ripple effects, ensuring a nuanced understanding of the curriculum's impact and fostering informed decisions in its continuous refinement.

A recurring lesson learned emphasises the importance of hands-on activities and experiential learning. The challenges that have been identified highlighted the necessity of providing personalised assistance and acknowledging the various thinking preferences that exist. The curriculum implications arising from this learning opportunity involved promoting a well-rounded approach that combines practical activities, experiential learning and a dedication to meeting the specific requirements of diverse groups of learners. This comprehensive approach guarantees a learning environment that is more inclusive and efficient.

Another essential insight underscores the significance of fostering analytical thinking and imaginative or creative self-expression. The challenges identified highlighted the importance of having patience, being adaptable and engaging in trial-and-error learning. The curriculum implications of this learning opportunity involved promoting a combination of analytical thinking and creative self-expression, acknowledging the importance of a supportive learning environment that values patience, adaptability and embraces the iterative nature of the learning process.

The learning opportunities highlighting the significance of promoting experimentation and iteration exposed difficulties associated with the requirement for concise explanations of fundamental constructs. The curriculum implications arising from this learning opportunity involved promoting a culture of experimentation and iteration, along with providing clear explanations for essential constructs. This comprehensive approach guaranteed that learners not only participated in practical experimentation but also gained from a thorough comprehension of the underlying theoretical principles.

The recurring theme highlighting the significance of practical experimentation in comprehending product performance exposed difficulties associated with the requirement for unambiguous learning opportunities and ongoing assistance. The curriculum implications derived from these learning opportunities emphasised the importance of integrating practical experimentation into the curriculum, along with the essential requirement for explicit learning opportunities and ongoing support. This comprehensive approach improved the overall learning experience of learners by ensuring that they received the necessary guidance and support to overcome challenges.

The significance of providing explicit guidance and support becomes evident when considering the difficulties in converting abstract shape constructs into functional code, as it ensures precise and accurate movements. The curriculum implications derived from these learning opportunities involved addressing challenges through clear guidance, assistance and fostering collaboration in coding tasks. The adoption of a collaborative and supportive approach cultivated an enhanced learning environment, guaranteeing that learners can conquer coding obstacles with aid and reciprocal support.

To summarise, the implementation of the Whole Brain® coding and robotics curriculum has yielded valuable insights that directly informed the curriculum implications. These entailments encompassed the promotion of a well-rounded approach to practical tasks, learning through direct experience, critical thinking and innovative self-expression. Moreover, a dedication to promoting trial-and-error, repetition and a nurturing learning atmosphere, combined with explicit guidance and ongoing assistance, established the basis for an enhanced and efficient educational encounter. The curriculum is still undergoing continuous development in response to these learning opportunities, guaranteeing its flexibility and effectiveness in addressing the varied requirements of Grade 4 learners.

6.6 Evaluating the impact of the Whole Brain® approach on THE coding and robotics curriculum

In this pivotal section, the focus shifts towards a critical examination of the impact made by the Whole Brain® approach within the realm of coding and robotics education. The comprehensive evaluation encompasses three distinct yet interrelated dimensions, exploring the 21st century competencies developed through this curriculum, exploring enhanced learning through Whole Brain® techniques and scrutinising the quality improvement aspect.

6.6.1 21st century competencies developed through the use of Whole Brain® thinking principles

This section delves into a meticulous analysis of the competencies honed by learners in the Whole Brain® coding and robotics curriculum, examining the impact of this innovative approach on analytical thinking, experimental thinking, practical thinking and relational thinking. By investigating learners' experiences and challenges, this exploration aims to provide valuable insights into the effectiveness of the curriculum in fostering key competencies.

The Whole Brain® coding and robotics curriculum fosters the growth of analytical thinking by nurturing problem-solving abilities. Learners encountered difficulties in conceptually representing real-life scenarios and developing basic structures, which required the implementation of problem-solving techniques. Theoretical knowledge is intentionally organised to give priority to problem definition, utilisation of sensors and storytelling, with the aim of creating an environment that encourages analytical thinking. Moreover, the importance of critical thinking becomes evident as it is demonstrated through the difficulties associated with justifying prototype selections and articulating observations. Critical thinking plays a crucial role in the cognitive development of learners, as it is intertwined with challenges related to problem formulation, sensor calibration and prototype selection. Analytical competencies are cultivated through the methodical organisation of learning opportunities and scrupulous focus on detail. The curriculum prioritises challenges that necessitate learners to translate abstract shape constructs into practical code, thereby highlighting the significance of cultivating analytical thinking. Furthermore, the process of evaluating and expressing observations and justifications in this context served to enhance and refine my data analysis competencies.

Within the domain of experimental thinking, creativity was fostered by the proficient execution of designated assignments that demonstrated learners' inventive thinking and coding abilities. Theoretical knowledge promoted Whole Brain® thinking strategies by emphasising the importance of organisation and efficient packing in fostering innovative thinking in practical situations. Innovation is actively promoted through hands-on experimentation, the development of prototypes and creative self-expression. The challenges associated with choosing the most suitable prototypes and understanding the differences between prototypes and final products emphasised the significance of innovation as a primary result of the curriculum. The importance of experiential learning, which involves active experimentation and practical application, was emphasised as a vital element that fostered a culture of experimentation and iteration. The learners' capacity to adapt to the ever-changing learning environment demonstrated their learning agility, which was highlighted by the iterative nature of the learning process and the encouragement of trial-and-error.

The curriculum places emphasis on practical thinking, highlighting the importance of adaptability, resilience and efficient time management. The need for adaptability and resilience arises from challenges encountered when adjusting to different circumstances, such as limited availability of tablets and spatial constraints. Likewise, the obstacles associated with construction, understanding and the testing procedure emphasised the significance of having patience, flexibility and a willingness to learn through experimentation. Time management competencies were cultivated as learners faced time limitations, fostering a vital skill for the 21st century. The curriculum focuses on tackling resource management difficulties, emphasising the significance of effective allocation and conscientious utilisation of technology in the presence of scarcity and infrastructure constraints.

Collaboration and teamwork promote relational thinking, as evidenced by enthusiastic collaboration, effective group support and cooperative learning environments. The positive aspects of teamwork, engagement and collaborative discussions are explicitly emphasised. Learners' communication competencies are demonstrated through their capacity to effectively engage in discussions, emphasising the significance of clear communication in the learning process and fostering a culture of experimentation and iteration. Promoting self-directed exploration and fostering learner independence was crucial, as it addressed the challenges associated with learners' hesitancy to engage in independent experimentation. Inclusive thinking was demonstrated by acknowledging the presence of diverse thinking preferences among learners and emphasising the significance of accommodating different cognitive modes of learning. Learners demonstrated inclusive thinking through their reflective processes, where they expressed their strengths, challenges and areas for improvement, highlighting the significance of effective communication during the learning journey.

The Whole Brain® coding and robotics curriculum was designed to foster the comprehensive development of 21st century competencies. It achieved this by incorporating analytical, experimental, practical and relational thinking into a dynamic and collaborative learning environment.

6.6.2 Assessing enhanced learning through Whole Brain® techniques

The assessment of Whole Brain® techniques in coding and robotics education involved a thorough examination of learners' cognitive engagement in analytical, experimental, practical and relational thinking. These facets provided a holistic understanding of how Whole Brain® methodologies impact learners' learning experiences in the coding and robotics curriculum.

6.6.2.1 Analytical thinking

Within the domain of coding and robotics, learners expressed a clear need for more detailed explanations that would help them better understand how components can be used in real-world situations. The statement about the need for clarification demonstrated a sincere desire to gain a more profound comprehension, indicating a cognitive inclination towards analytical thinking. This inclination indicated a strong desire to go beyond superficial understanding and comprehending the complexities of how individual elements function within the wider scope of practical implementation.

Learners' meticulous execution of sequential guidelines for constructing structures exemplified their exceptional analytical abilities. The learners' scrupulous focus on logical sequences and meticulous execution not only demonstrated their dedication to the task but also exemplified analytical thinking within quadrant A. The meticulousness and methodical approach displayed in adhering to structured guidelines for constructing buildings highlighted their capacity to tackle tasks in a systematic and deliberate manner.

In addition, when analysing the Whole Brain® thinking framework, learners demonstrated an impressive ability to deconstruct intricate problems into manageable elements. The process of breaking down challenges was not done solely to make them simpler but was also accompanied by a careful evaluation process with the goal of selecting the best possible solutions. The learners demonstrated their strong analytical competencies by systematically constructing logical sequences for their projects. This approach was in perfect harmony with analytical thinking, which prioritises a methodical and comprehensive analysis of problems prior to moving forward with the implementation stage.

Essentially, the learners expressed a desire for additional explanations, combined with their skilful involvement in sequential instructions and their effective problem-solving techniques, collectively indicating a strong alignment with analytical thinking. Their analytical inclination was apparent not only in their careful attention to detail but also in their systematic breakdown of challenges and methodical creation of logical sequences. This highlighted their dedication to fostering a more profound and comprehensive understanding of coding and robotics activities.

6.6.2.2 Practical thinking

The learners demonstrated their proficiency in practical thinking by effectively carrying out a sequence of actions, thereby displaying their capacity to comprehend and adhere to the logical progression presented by the tablet. The learners displayed a systematic approach to problem-solving and task execution by following this organised and logical sequence. In addition, their involvement encompassed the examination of components, which entailed direct manipulation of technological elements. The empirical experimentation demonstrated a concrete utilisation of knowledge, highlighting the significance of direct engagement with the materials and tools used in coding and robotics tasks.

Within the wider context of Whole Brain® thinking, learners demonstrated a tangible implementation of their cognitive capacities. Their methodical deconstruction of problems into intricate particulars underscored an analytical and pragmatic approach to challenges. In addition, the learners demonstrated the practical connection between sounds and colours, highlighting a tangible, sensory-based comprehension of coding constructs. This practical application also encompassed the use of visual aids, which offered a concrete and visual depiction of information. The learners exhibited a comprehensive approach to learning by integrating practical thinking into the planning and programming stages of their activities.

Practical thinking was demonstrated by sequential and hands-on interaction with technological components, which corresponded to the logical flow presented by the tablet. The implementation of Whole Brain® thinking enhanced their practical approach by prioritising thorough problem analysis, establishing practical connections between sounds and colours and utilising visual aids effectively. The combination of practical and Whole Brain® thinking highlighted the learners' capacity to not only understand theoretical knowledge but also effectively apply that knowledge in the practical aspects of planning and programming in the coding and robotics field.

6.6.2.3 Relational thinking

The learners exhibited a distinct display of relational thinking through their difficulties with standing preference and the task of retaining components during discussions. This observable struggle indicated an awareness of the relationships between physical actions and the input received from sensors. The learners' difficulties in maintaining a standing preference and holding onto components underscored a recognition of the relational dynamics between their physical movements and the corresponding responses generated by the sensors. This awareness indicated a cognitive engagement in comprehending and manoeuvring the complex connections between their actions and the sensory inputs within the coding and robotics domain.

The incorporation of force and colour sensors into learner activities further demonstrated quadrant C thinking. The learners showed a tendency to comprehend and utilise relational aspects in their projects by integrating these advanced sensors. The incorporation of force and colour sensors demonstrated an advanced comprehension of the interplay between these elements and the surroundings, exemplifying a relational thinking methodology rooted in experimentation and technological investigation.

Within the context of Whole Brain® thinking, learners actively participated in managerial tasks such as team management, work organisation and engaging in discussions. This active engagement demonstrated a mindset that focuses on relationships, highlighting the importance of acknowledging and fostering successful teamwork and collaboration. Learners exhibited comprehension of the interrelatedness and mutual reliance of team dynamics through the management of teams and coordination of tasks. Their participation in discussions highlighted their ability to think in terms of relationships, emphasising the significance of effective communication and collaboration in attaining shared objectives.

To summarise, the difficulties faced by the learners in terms of their preference for standing and handling components demonstrated a sophisticated understanding of the connections between physical actions and sensory input, highlighting their ability to think in terms of relationships. The incorporation of force and colour sensors exemplified quadrant C thinking, highlighting a more profound comprehension of the interconnections among technological elements. Within the Whole Brain® thinking framework, active participation in team management and discussions highlighting relational thinking. This emphasised the importance of efficient teamwork and collaboration in the coding and robotics educational setting.

6.6.2.4 Experimental thinking

The learners demonstrated an impressive level of skill in their capacity to understand and apply their knowledge to different scenarios. They conducted systematic experiments involving motors and sensors. This demonstration of skilled conceptualisation and practical experimentation is in line with quadrant D thinking, which represents an approach based on experimental thinking and a problem-solving methodology that involves repeated iterations.

The learners' incorporation of a distance and colour sensor into their activities clearly demonstrated their experimental mindset. Through the incorporation of these sophisticated elements, the learners showcased not only a readiness to delve into more complex features but also displayed a creative method of resolving problems. The utilisation of these sensors demonstrated a purposeful endeavour to augment the intricacy and functionalities of their projects, highlighting a quadrant D thinking approach focused on experimentation and improving their solutions through iterative trials.

Within the framework of Whole Brain® thinking activities, learners actively participated in the creation of new problems, proposing alternative solutions and ultimately completing projects. This diverse involvement showcases both ingenuity and a willingness to explore novel constructs. The learners' capacity to generate novel challenges and suggest alternative solutions demonstrates a comprehensive cognitive approach that integrates both creative and analytical thinking elements. Their exhibited willingness to further investigate novel constructs highlights a dynamic and adaptable mindset, which is a characteristic of Whole Brain® thinking.

To summarise, the learners' ability to understand constructs, experiment with different parts and engage in Whole Brain® thinking activities demonstrates a strong and comprehensive approach to learning. Their proficiency in quadrant D thinking, characterised by conducting experiments and engaging in iterative problem-solving, demonstrated their ability to learn through practical experience. At the same time, their participation in Whole Brain® thinking activities showed a comprehensive cognitive engagement that included creativity, analytical thinking and a readiness to explore and innovate within the coding and robotics field.

This comprehensive evaluation revealed that Whole Brain® techniques not only cater to analytical and experimental thinking but also foster practical and relational thinking among learners. The incorporation of these cognitive approaches in the robotics curriculum ensured a well-rounded and enriched learning experience. Learners' engagement with Whole Brain® activities showcased a multifaceted development of their cognitive competencies, contributing to a more profound understanding of coding and robotics constructs.

6.6.3 Analysing the quality improvement aspect

This section explores the qualitative aspects of the robotics education programme, specifically examining journal entries that highlight the strengths, challenges and observed improvements of learners. The exploration seeks to uncover the intricate dynamics of learners' experiences, offering vital insights for improving and progressing the curriculum.

6.6.3.1 Analysis of learner reflections

Upon analysing the reflections of learners, it becomes evident that there are consistent strengths in terms of enthusiasm, collaboration and problem-solving abilities, which emerge as prominent themes. These attributes demonstrated active involvement with the curriculum, thereby enhancing the overall aspect of quality improvement. The challenges identified by the learners provided valuable insights for designing future learning opportunities, illuminating areas that may necessitate additional attention or alternative strategies to facilitate and assess learning. The learners' reflective processes showcased their dedication to ongoing improvement, rendering these journal entries invaluable assets for refining and enhancing future curriculum development.

6.6.3.2 Advantages and limitations

When evaluating the benefits of active engagement, cooperation and problem-solving abilities, learners also acknowledged the drawbacks that require attention.

The identified weaknesses provided a thorough understanding of the landscape of quality improvement, offering valuable insights for improving future learning opportunities. This methodical approach to assessing both advantages and disadvantages placed the curriculum in a favourable position for gradual improvement and more sophisticated methods of facilitating and assessing learning.

The learners were actively involved in testing and analysis, which is a notable strength. However, challenges that have been identified during this process revealed underlying weaknesses that need to be addressed with focused attention. The repeated process of involvement, recognition of difficulties and thoughtful understanding demonstrated the ongoing enhancement of the curriculum's quality. Recognising weaknesses served as a catalyst for focused enhancements, guaranteeing a stronger and more efficient educational experience.

The learners exhibited commendable strengths by displaying enthusiasm, critical thinking and spatial reasoning competencies. The highlighted challenges underscored the significance of tailored guidance and adaptable strategies, revealing inherent vulnerabilities. The incorporation of critical thinking and spatial reasoning abilities enhanced the curriculum's effectiveness, although the recognised deficiencies highlighted the need for a more individualised and flexible approach in certain areas. This combined evaluation promoted a comprehensive understanding of the quality enhancement environment.

6.6.3.3 Reflecting on my journal entries

The learners demonstrated strengths in their enthusiasm, proficiency in learning opportunity structures and creativity in shape design. Challenges that highlighted the significance of clear direction and assistance offer detailed insights for enhancement. The process of reflection, documented in journal entries, demonstrated the continuous enhancement of learners' involvement in quality improvement. The identified areas for guidance and support are crucial factors to consider when improving and enhancing the curriculum, to ensure a more comprehensive and efficient educational experience.

To summarise, the examination of journal entries did shed light on the enhancement of quality in coding and robotics education by identifying its strengths and challenges. The active participation, thoughtful analysis and collaborative perspectives of learners were essential components for continuously improving and developing a curriculum that is both effective and influential.

6.7 Investigating the contribution of the backward design approach

This section delves into a comprehensive investigation aimed at understanding the impact and nuances of the backward design approach in the context of curriculum development for coding and robotics. The exploration was conducted using two distinct lenses, namely exploring the role of backward design in curriculum development and assessing the extent to which backward design had an influence on effectiveness and engagement. Together, these sub-sections wove a narrative that not only explored the theoretical underpinnings of the backward design approach but also critically evaluated its practical implications. By unravelling its role and assessing its influence on effectiveness and engagement, this section contributes to the ongoing dialogue on shaping robust, learner-centric Whole Brain® coding and robotics curricula.

6.7.1 Exploring the role of backward design in curriculum development

This sub-section serves as a compass, guiding me through the intricate landscape of the backward design approach's role in the development of the coding and robotics curriculum. By undertaking a detailed exploration, I wanted to uncover how the approach shaped the logical flow of coding instructions and underscored practical application requirements. This analysis unveiled the foundational components that contributed to a coherent and effective curriculum development process.

The learning opportunities observation forms clearly demonstrated the consistent inclusion of backward design components, specifically in the establishment of a coherent sequence based on tablet instructions and the integration of instructions for practical implementation, such as turning the hub on and off. The intentional methodology greatly enhanced the overall efficacy of the Whole Brain® coding and robotics curriculum by guaranteeing a purposeful and organised educational encounter.

The learning opportunities observation forms highlighted the significance of incorporating backward design components beyond tablet-based instructions, emphasising the necessity of practical application requirements. The recognition of these components in the coherent sequence of directions additionally amplified the efficacy of the curriculum. The deliberate incorporation of backward design enhanced the seamless amalgamation of theoretical knowledge and practical application, promoting a comprehensive and purpose-driven educational experience.

Backward design components remained a fundamental aspect in shaping coding and robotics education. This deliberate design approach guaranteed a consistent and purpose-driven educational experience that is in line with the overall curriculum objectives. By prioritising the logical progression of learning opportunities, the practical demands of real-world application, educators can design a curriculum that highlights a deliberate combination of theoretical comprehension and practical execution.

Although backward design components are commonly included, certain learning opportunities observation forms demonstrated a deficiency in explicitly addressing these principles. This absence necessitated a thorough evaluation of the possible prioritisation of short-term goals over a holistic, enduring strategy for curriculum development. Further investigation is required to explore the education philosophy guiding these learning opportunities and its alignment with broader educational objectives, due to the recurring absence of explicit backward design components.

To summarise, the analysis of the learning opportunities observation form data highlighted the crucial influence of backward design components on the development of the Whole Brain® coding and robotics curriculum. The deliberate incorporation of coherent progression and pragmatic implementation criteria enhanced an educational encounter that is both meaningful and focused on achieving objectives. The lack of clear backward design components in certain cases determines a need for further consideration of the underlying pedagogical approaches. This will encourage educators to think about how the immediate objectives will align with the overall curriculum goals.

6.7.2 Assessing the extent to which backward design influenced effectiveness and engagement

In this critical dimension, my focus sharpens on evaluating the real-world impact of the backward design approach. By assessing its influence on the effectiveness of the curriculum and the engagement levels of learners, I aimed to explore the extent to which this approach translates theoretical foundations into tangible educational outcomes. This assessment provided valuable insights into refining and optimising the backward design approach for future implementations.

Various obstacles arose during the implementation, such as initial struggles in constructing fundamental structures and comprehending the practical use of the distance sensor. Although the use of backward design is recognised for its contribution to overall effectiveness, the identified challenges emphasised the need for transformation. It is crucial to focus on addressing challenges related to engagement and understanding in order to maximise the impact of backward design on the success of the curriculum.

Furthermore, the difficulties associated with creating practical and pertinent problem statements and ensuring consistency during testing are acknowledged. The conclusion highlighted the beneficial impact of backward design on effectiveness, while also emphasising the need to improve the approach to tackle challenges related to engagement and problem formulation.

The recurring challenge of consistency during testing suggested the potential necessity of refining backward design components to ensure a more robust and consistent learning experience. This observation highlighted the importance of carefully adjusting the process of backward design, particularly in ensuring coherence during practical assessments.

The challenge lies in identifying a customised organisational system that caters to the unique needs of individual learners. This prompts a contemplation on the necessity of enhancing the components of backward design to accommodate the individual preferences of learners and to optimise organising strategies. The difficulties in this area emphasised the significance of customising curriculum components to accommodate the varied learning requirements of each learner.

In my journal reflections, challenges pertaining to the precise alignment of movements to achieve desired shapes are acknowledged. The recurrence of this challenge throughout reflections indicated a possible domain for enhancing backward design components. It is crucial to focus on precise movement alignment to enhance the effectiveness of the curriculum, particularly in shaping formation.

To summarise, backward design unquestionably enhances the overall efficacy of the Whole Brain® coding and robotics curriculum. However, the identified challenges indicated a necessity for further enhancement. These challenges highlighted the significance of customising backward design components to tackle specific concerns regarding engagement, problem definition, coherence and personalised learning preferences. By refining backward design in these areas, the influence of the curriculum on effectiveness and learner engagement can be greatly optimised.

6.8 Navigating the labyrinth of research questions

In this pivotal section, I intricately weave together the essential elements of my scholarly journey. I start with the secondary research questions that form the basis of my primary research question, delve into the empirical findings obtained through thorough examination, and seamlessly incorporate these discoveries into the wider scholarly discourse. The foundation of my collective narrative lies in a re-examination of the primary research question, which guided my investigation into the areas of action research, self-monitoring and curriculum design specifically for Grade 4 learners. Next, the investigation delved into the secondary research questions, with each one providing additional insights that contributed to my overall comprehension of the research field. These questions included: What pre-existing conditions need to be in place to implement an action research-driven Whole Brain® coding and robotics curriculum? What will an action research-driven Whole Brain® coding and robotics curriculum entail? How did the Whole Brain® approach enhance the quality of the coding and robotics curriculum for Grade 4 learners? To what extent did the backward design approach contribute to the development of an effective and engaging coding and robotics curriculum for Grade 4 learners? Each of these questions played a crucial role in shaping my methodology and informing the direction of my research, ultimately leading to a more comprehensive understanding of how to effectively implement a Whole Brain® coding and robotics curriculum in a Grade 4 classroom setting. These inquiries lead me to explore the pre-existing conditions required for implementing a curriculum that combines action research, Whole Brain® coding and robotics. I broadened my focus to include the complexities of this curriculum, exploring its various elements and organisation. Furthermore, I analysed the influence of the Whole Brain® approach on the curriculum's quality for

Grade 4 learners, while also evaluating how the backward design approach contributed to its effectiveness and level of engagement.

6.8.1 The secondary research questions

In this section, my scholarly journey unfolds, beginning with a meticulous exploration of the secondary research questions. This deliberate choice served as the cornerstone of my research methodology, laying the groundwork for a comprehensive understanding of the broader context surrounding my primary research question. I explain what pre-existing conditions needed to be in place to implement an action research-driven Whole Brain® coding and robotics curriculum, what such a curriculum entailed, how the Whole Brain® approach enhanced the quality of the coding and robotics curriculum for Grade 4 learners, and to what extent the backward design approach contributed to the development of an effective and engaging coding and robotics curriculum for Grade 4 learners. As I navigated through these secondary questions, I unearthed valuable insights that are not only informed but also intricately connected with the overarching narrative of my investigation.

6.8.1.1 Identifying pre-existing conditions for implementing an action research-driven Whole Brain® coding and robotics curriculum

In the realm of education, the integration of coding and robotics has emerged as a pivotal component, particularly in preparing learners for the challenges of the digital era. However, for these subjects to be effectively implemented, schools must meet certain prerequisites, particularly concerning infrastructure, resources and educators that are specialised in the field.

Infrastructure and resources are crucial requirements for the successful implementation of coding and robotics in schools. Schools require up to date computer labs with modern hardware and software to enhance interactive learning experiences. El-Hamamsy, et al. (2021) and CAPS123 (2023) suggest that schools should invest resources in creating modern computer labs equipped with cutting edge facilities to improve interactive learning experiences. Having these resources is essential for creating an engaging and interactive learning environment (El-Hamamsy et al., 2021; Screpanti et al., 2021). Based on my research and experience, having essential equipment like LEGO® robotic sets and tablets is vital for successful implementation. During the introduction of the curriculum, my learners and I faced challenges because we lacked these resources. I had to develop the programming code for learners and schedule the use of the ICT computer lab, which was frequently occupied. Delivery delays of new sets caused bigger group sizes, affecting the dynamics of the learning opportunities and occasional conflict. Additionally, I encountered difficulties with learners assuming limited roles in groups, where one learner acted as the builder while the others observed. Having tablets would have allowed for a more orderly division of roles, ensuring that everyone had an opportunity to participate in the building process. Having modern computer labs and technological tools are essential, but it is equally crucial to have specific equipment such as robotics kits and tablets to create an engaging and interactive learning environment for coding and robotics education. These resources are essential for effective implementation and should be given high priority in schools.

Alongside infrastructure, the proficiency of educators is equally crucial. Highly proficient educators with a deep understanding of coding and robotics are essential for effectively implementing the curriculum. Educators should engage in professional development programmes to stay current with the latest technological advancements. Moreover, hiring educators who have a strong passion for coding and robotics can spark enthusiasm and drive in learners, improving their educational trajectory. According to Screpanti, et al. (2021), educators should participate in professional development programmes to remain up to date with the latest technological advancements. Yildiz and Seferoglu (2021) explain that it is crucial to prioritise the recruitment of educators who possess a passion for coding and robotics, as their enthusiasm has the potential to ignite inspiration and motivation among learners. In my study, it is evident that having a programming background was beneficial. As someone who is self-taught in programming, I believe I would not have been able to teach effectively without this basic knowledge. However, I still struggled from time to time, particularly when I forgot some programming principles. For example, I sometimes overlooked the importance of first stating the power at which the motor should turn before stating that the motor should start. These challenges highlighted the need for continuous learning and improvement in my own proficiency in coding and robotics, underscoring the importance of educators being proficient in these disciplines for the successful implementation of the curriculum.

Furthermore, inclusive education practices are paramount for ensuring that coding and robotics programmes cater to learners of diverse backgrounds, abilities and interests. Inclusive education practices are crucial for coding and robotics programmes, ensuring that they are designed to accommodate learners with diverse backgrounds, abilities and interests. Educational institutions should establish an inclusive environment that motivates all learners, regardless of gender or socio-economic background, to engage in coding and robotics activities. It is essential to address potential obstacles, such as access to technology, to guarantee equal opportunities for all learners. As evidenced in my study, not all learners had the opportunity to work with computers or robotic sets before, highlighting the importance of inclusivity in providing equal access to these educational tools and opportunities. Efforts should be made to create a welcoming environment that encourages all learners to participate, regardless of their background or abilities (Women in Digital Empowerment, 2020; Díaz-Boladeras et al., 2023).

Identifying pre-existing conditions is crucial for successfully integrating an action research-driven Whole Brain® coding and robotics curriculum into educational institutions. Educational institutions can effectively implement the curriculum by addressing infrastructure and resource needs, ensuring educator proficiency, promoting inclusive education practices and establishing a strong assessment system. This will offer learners opportunities to achieve the necessary competencies and knowledge for success in the digital era.

6.8.1.2 An action research-driven Whole Brain® coding and robotics curriculum

An action research-driven Whole Brain® coding and robotics curriculum represents a holistic approach to developing a coding and robotics curriculum, incorporating principles of both action research and Whole Brain® thinking. This section explores the key components of such a curriculum, highlighting its effectiveness in promoting comprehensive learning outcomes.

In the realm of education, the fusion of coding and robotics has emerged as a powerful pedagogical approach. The Whole Brain® Coding and Robotics Curriculum, grounded in action research, seeks to engage learners holistically by integrating cognitive, emotional and kinaesthetic dimensions. As discussed in section 2.2.5.5, Whole Brain® learning is an approach to facilitating and assessing learning that aims to engage all parts of the brain in the learning process. Many researchers have explained that in order to assist learners in learning in a method that is most conducive to their particular learning preferences, it places an emphasis on the utilisation of a range of learning modes, including visual, auditory, reading, writing and kinaesthetic (De Boer et al., 2001; De Boer et al., 2015; Deshpande, 2010; Herrmann-Nehdi, 2010; Herrmann Global LLC, 2022).

In summary, this model suggests that the brain is divided into four quadrants. The right hemisphere is predominant in people who learn best visually, and which is predominant in people who learn best by hearing, as linked to creative, intuitive and spatial thinking. In contrast, logical, analytical and linguistic thinking are linked to the right hemisphere (De Boer et al., 2013; Herrmann-Nehdi, 2010; Herrmann, 1995). The top region of the brain is important for reading and writing abilities and predominant in people who learn best through reading and writing (De Boer et al., 2013; Herrmann-Nehdi, 2010; Herrmann, 1995). The bottom region of the brain is predominant in people who learn best through kinaesthetic or hands-on methods (De Boer et al., 2013; Herrmann-Nehdi, 2010; Herrmann, 1995).

Discovery learning and guided learning modes are recognised as crucial components in this Whole Brain® coding and robotics curriculum. The primary focus of the curriculum is on constructing structures, utilising the central hub and sensors and participating in executing practical tasks. The comprehensive approach incorporates diverse methods of facilitating and assessing learning, emphasising a holistic learning experience that integrates theoretical knowledge with real-world application. This approach aligns with the HBDI® quadrants, which categorise learners based on their thinking preferences into Analytical (A), Practical (B), Relational (C) and Experimental (D) quadrants.

Constructivism, group work and experiential learning are acknowledged as methods of facilitating and assessing learning in another set of important components. The curriculum focuses on the identification of problems, the utilisation of sensors and the generation of narratives through coding. The combination of constructivism, collaborative learning and experiential learning results in a versatile approach to facilitating and assessing learning, catering to learners across all HBDI® quadrants. The challenges associated with maintaining consistency during assessment highlight the significance of providing clear learning outcomes, particularly for learners in the Analytical (A) quadrant, who thrive on structured and logical approaches.

The following collection of essential components includes collaborative work, hands-on learning and an emphasis on creating prototypes. The achievement of effectively involving learners in comprehending prototypes is an essential factor, highlighting the importance of collaborative learning, practical experiences and a focus on comprehending and creating prototypes, which are particularly beneficial for learners in the Experimental (D) quadrant.

The recurring presence of fundamental components such as guidance and experiential learning, coupled with difficulties in ensuring uniformity during assessments, highlights the continuous significance of these components, catering to learners in all HBDI® quadrants. The conclusion highlights the importance of collaborative learning and facilitation, along with the chance to improve instructional clarity to effectively tackle challenges, benefiting learners in the Analytical (A) and Practical (B) quadrants.

From a broader standpoint, the curriculum implementation emphasised the significance of practical experimentation in comprehending product performance. The challenges identified showed the necessity of providing explicit learning opportunities and ongoing support throughout the learning process, benefiting learners across all HBDI® quadrants. The curriculum entails the incorporation of practical experimentation, explicit learning guidance and a consistent support system to improve the overall learning experience, ensuring that learners representing all the quadrants are supported according to their preferences.

In essence, the identification and definition of crucial components in the Whole Brain® coding and robotics curriculum make a substantial contribution to educational practices. Having a thorough comprehension of the subject matter allows educators to create and execute a curriculum that not only encourages active thinking and practical abilities but also effectively tackles obstacles by providing explicit guidance and ongoing assistance, catering to learners' preferences across all HBDI® quadrants.

6.8.1.3 Enhancing the coding and robotics curriculum for Grade 4 learners through the Whole Brain® approach

a) 21st Century competencies developed by the Whole Brain® techniques

The Whole Brain® approach focuses on developing a range of 21st century competencies essential for success in the modern world. These competencies include critical thinking, creativity, collaboration and communication (Budhai & Taddei, 2015; Rifandi & Rahmi, 2019; Stauffer, 2019, 2022; Van Laar et al., 2017). By integrating these competencies into the coding and robotics curriculum, learners are not only learning technical concepts but also developing the competencies needed to apply in real-world scenarios.

In the context of robotics education, learners are tasked with developing a range of technical, problem-solving, cognitive and interpersonal competencies. Technical competencies encompass activities such as powering the hub on and off, connecting and programming motors and integrating sensors for specific functions. Problem-solving competencies are exercised in conceptualising real-world applications, adjusting programming logic based on feedback and synthesising knowledge to construct functional robots. Cognitive competencies, including analytical, practical, relational and experimental thinking, are essential for navigating technical complexities, executing physical connections, collaborating effectively and exploring different approaches. Creativity and innovation play a crucial role, as learners experiment with light patterns, sound triggers and sensor responses. Collaboration and communication competencies are honed through teamwork and articulation of construction processes. Adaptability and resourcefulness are demonstrated in response to equipment delays and challenges, while interpersonal competencies are enhanced through collaborative problem-solving. Experiential learning is central, allowing learners to deepen their understanding through hands-on experimentation and fostering a culture of exploration and innovation. Reflection and self-assessment are integral components, enabling learners to identify strengths, challenges and real-world applications of their learning.

In conclusion, the Whole Brain® approach to coding and robotics education not only equips learners with technical knowledge but also fosters the development of essential 21st century competencies. Through hands-on learning and real-world applications, learners are able to enhance their critical thinking, creativity, collaboration and communication competencies. By integrating these competencies into the curriculum, educators are preparing learners to succeed in an increasingly complex and interconnected world, where the ability to adapt, innovate and work effectively with others is paramount.

b) Analysing the quality enhancement aspect

One of the key aspects of the Whole Brain® approach is its focus on quality enhancement. By continually evaluating and refining the curriculum, educators can ensure that it remains relevant and effective. This can involve updating content to reflect the latest advancements in coding and robotics, as well as incorporating feedback from learners and educators to address any areas that need to be transformed.

One of the key methods for assessing learning is through observation. By actively observing learners as they engage with the curriculum, educators can gain valuable insights into their understanding and progress (De Boer et al., 2013; Mind Tools, 2024). This allows educators to identify areas where learners may be struggling and adjust the curriculum accordingly. Observing learners as they work on coding and robotics tasks provided me with a direct view of how learners approach problems, use coding concepts and interact with robotics components. Through observation, I assessed learners' problem-solving competencies. I observed how learners analyse challenges, develop strategies and apply coding principles to find solutions. This insight helped me understand learners' cognitive processes and learning strategies. Observing learners also allowed me to gauge learners' understanding of coding and robotics concepts. I assessed whether learners grasped fundamental programming concepts, such as loops, conditionals and variables, and how effectively they applied these concepts in their projects. Continuous observation over time enabled me to track learners' progress and mastery of coding and robotics competencies. By observing learners' performance in various tasks and projects, I identified areas of improvement and provided targeted support to help learners achieve mastery. Observation helped me to identify areas where learners were struggling. Whether it was difficulty in understanding a specific programming concept or challenges in working with robotics components, or the actual programming code, observation allowed me to pinpoint these challenges and provide tailored interventions to support learner learning. Lastly, based on observations, I could adjust the curriculum to better meet the needs of learners. For example, if an observation revealed that learners were struggling with a particular coding concept, I could modify instructional strategies or provide additional resources to address these challenges.

Incorporating relevant assessment strategies into the curriculum allowed me to continually evaluate and improve the effectiveness of the Whole Brain® approach in enhancing learner learning. By tailoring the curriculum to meet the needs of individual learners, educators can ensure that learners are enabled to achieve success in coding and robotics.

6.8.1.4 The contribution of the backward design approach to an effective and engaging coding and robotics curriculum for Grade 4 learners

The backward design approach is a powerful framework for creating effective and engaging coding and robotics curricula for Grade 4 learners. This approach, popularised by Grant Wiggins and Jay McTighe (2005), emphasises starting with the end goals in mind and working backwards to develop the curriculum. As explained in section 2.1.1.1, it consists of three main stages: identifying desired results, determining acceptable evidence and planning learning opportunities with enhanced learning experiences in mind (Emory, 2014; Ornstein & Hunkins, 2018). In the context of coding and robotics, this approach was particularly beneficial for creating a curriculum that is both meaningful and impactful for young learners.

One of the key contributions of the backward design approach is its focus on clearly defining learning outcomes (Wiggins & McTighe, 2005). By starting with the end goals in mind, educators can ensure that the curriculum is aligned with specific learning objectives (Education Reform, 2013; Wiggins & McTighe, 2005), commonly referred to as learning outcomes in the South African context. For a coding and robotics curriculum, these objectives include developing computational thinking competencies, problem-solving abilities and an understanding of basic programming concepts. In my study, I highlighted the importance of the backward design approach in crafting a logical sequence of coding instructions. This method ensures that each coding learning opportunity – commonly referred to as a lesson in the South African school context – builds upon the previous one, creating a logical flow of concepts and competencies. This logical progression is vital for learners as it helps them understand how each new piece of coding knowledge fits into the bigger picture.

Another important contribution of the backward design approach is its emphasis on assessment (Knowledge Base, 2021). In the backward design framework, assessment is not an afterthought but an integral part of the curriculum design process (Emory, 2014). Educators are encouraged to think about how they will assess learner learning from the outset, which can help ensure that assessment strategies are aligned with learning objectives (Wiggins & McTighe, 2005). In the context of this Whole Brain® coding and robotics curriculum, this involved using a variety of assessment methods, such as project-based assessment, quizzes, reflections and peer evaluations, to measure learner progress and understanding.

Additionally, the backward design approach encourages educators to plan learning experiences and instruction that are engaging and meaningful for learners (Education Reform, 2013; Emory, 2014; Wiggins & McTighe, 2005). By starting with the end goals in mind, I designed tasks and projects that are relevant to learners' interests and experiences. For example, I incorporated real-world problems and challenges into the curriculum in Cycle 2 to 6 and 8 to 14, allowing learners to apply their coding and robotics competencies in authentic contexts. This can help increase learner engagement and motivation, leading to a more effective learning experience overall.

In conclusion, the backward design approach is a valuable framework for creating effective and engaging coding and robotics curricula for Grade 4 learners. By starting with the end goals in mind, educators can ensure that the curriculum is aligned with specific learning objectives, assessment strategies are aligned with learning objectives, and learning experiences and facilitating of learning are engaging and meaningful for learners.

6.8.2 The primary research question

This detailed section significantly contributed to answering the main research question regarding the development of the coding and robotics curriculum for Grade 4 learners. It specifically addressed the integration of action research principles and Whole Brain® thinking into the curriculum design and continual development process. By identifying pre-existing conditions for implementing the curriculum, discussing the curriculum's key components and highlighting the enhancements brought about by the Whole Brain® approach, this section offered a comprehensive framework for self-monitoring of the development of the curriculum.

The section on pre-existing conditions underscored the critical nature of several pre-existing conditions for the successful implementation of the coding and robotics curriculum for Grade 4 learners. It emphasised the necessity of adequate infrastructure, including up to date computer labs with modern hardware and software, to facilitate interactive learning experiences. Additionally, the availability of resources such as LEGO® robotic sets and tablets was highlighted as essential for creating an engaging and interactive learning environment. Educator proficiency was also deemed essential, with a focus on the need for educators to stay current with the latest technological advancements through professional development programmes. Moreover, the section stressed the importance of inclusive education practices to ensure that the curriculum caters to learners of diverse backgrounds, abilities and interests. By outlining these conditions, educators could evaluate their readiness to implement the curriculum and make necessary adjustments to meet these requirements, thereby enhancing the chances of successful curriculum implementation.

The section on an action research-driven curriculum design section elaborated on the key components of an action research-driven Whole Brain® coding and robotics curriculum, aiming to engage learners holistically and accommodate diverse learning preferences. It highlighted the importance of discovery learning, where learners actively explore and construct knowledge, and constructivism, which emphasises the role of prior knowledge and experience in learning. Additionally, the section emphasised the value of group work, allowing learners to collaborate and learn from one another, and experiential learning, which provides hands-on experiences to reinforce learning. These components collectively formed a framework for designing a curriculum that not only ensured mastering technical knowledge but also fostered critical 21st century competencies such as problem-solving, creativity, collaboration and communication.

The Whole Brain® approach enhancement section delved into how the Whole Brain® approach enhanced the coding and robotics curriculum for Grade 4 learners by developing essential competencies for success in the modern world. By integrating

21st century competencies such as critical thinking, creativity, collaboration and communication into the curriculum, learners not only acquired technical knowledge but also developed competencies necessary for navigating the complexities of the digital era. This approach was instrumental in ensuring that learners had a comprehensive learning experience that not only focused on technical concepts but also emphasised the application of knowledge in real-world scenarios. Overall, the Whole Brain® approach was considered as a valuable means of enhancing the curriculum, ensuring that learners were not only well versed in coding and robotics but mastered competencies that would serve them well in their future endeavours.

Overall, this study provided a comprehensive overview of the development of the coding and robotics curriculum for Grade 4 learners, highlighting the importance of integrating action research principles and Whole Brain® thinking. By addressing pre-existing conditions, discussing key components and highlighting the enhancements brought about by the Whole Brain® approach, this section offered valuable insights for educators seeking to develop and refine their coding and robotics curriculum.

6.9 My professional development

During my study, I focused on incorporating innovative methods of facilitating and assessing learning like Whole Brain® thinking into my teaching practice to enhance my professional development. My thinking preference profile indicates a strong inclination towards left mode thinking, which signifies a preference for logical and analytical thinking. This preference reflects my expertise in Computer-Integrated Education and my self-acquired programming competencies, demonstrating my ease with organised, technical ideas.

My cognitive preferences lean towards lower mode thinking, characterised by detail orientated and methodical approaches. Implementing Whole Brain® thinking, which emphasises holistic, creative thinking, may have been challenging due to this preference. To enhance my lessons using the Whole Brain® approach, I needed to step out of my comfort zone and integrate more right mode thinking, which includes intuition, imagination and holistic thinking.

My change in thinking preference shows my adaptability and readiness to move beyond my comfort zone to address the varied needs of my learners. By integrating Whole Brain® thinking into my curriculum, I have improved my methods of facilitating and assessing learning and offered my learners a more stimulating and efficient learning environment. Being able to combine various thinking modes and approaches is a valuable skill that helped me in my professional growth as an educator.

By reflecting on lessons like “Building with LEGO® Blocks” and “Exploring Sensors”, I have enhanced my competencies in facilitating hands-on, experiential learning. Although facing obstacles like learners struggling with basic construction, I realised the significance of offering personalised assistance and promoting tasks with open-ended possibilities. In the lesson about “Problem Definition” and “Creativity with KIKI Spike Prime™”, I enhanced my ability to balance analytical thinking and creative self-expression. I also gained insights into the importance of patience and adaptability.

I have demonstrated progress in fostering experimentation and iteration in lessons such as “Understanding Prototypes” and “Making Informed Choices with Hopper Spike Prime®”. I discovered that clear explanations and collaborating with peers are crucial for improving the quality of prototypes. These experiences have enhanced my methods of facilitating and assessing learning and broadened my comprehension of the obstacles and possibilities in coding and robotics education for Grade 4 learners.

My professional growth during this study has been defined by a readiness to learn and adjust. By adopting innovative methods and pushing beyond my usual boundaries, I have enhanced the educational experience for my learners. I have a thoughtful approach to teaching and am dedicated to enhancing the learning experience for my learners, as evident in my reflections.

Moving forward, I will continue to embrace new approaches and integrate different thinking modes and approaches into my teaching practice. By doing so, I aim to ensure a more engaging and effective learning experience for my learners, by designing learning opportunities that will promote mastering the competencies and knowledge necessary for success in the 21st century.

6.10 Conclusion

In conclusion, Chapter 6 has explored the complex field of education by conducting a thorough examination of Whole Brain® coding and robotics. During this educational journey, I encountered various challenges and opportunities while developing a comprehensive coding and robotics curriculum for Grade 4 learners. The study has thoroughly analysed the point where theoretical knowledge and practical application meet, revealing the intricate dynamics that influence educational transformation. I also examined my secondary research questions that underpinned my primary research inquiry. These questions not only provided additional insights into action research, self-monitoring and curriculum design for Grade 4 learners. but also guided my exploration of the pre-existing conditions necessary for integrating action research principles and Whole Brain® thinking into the curriculum.

The inquiry into pre-existing conditions for the implementation of the action research-based Whole Brain® coding and robotics curriculum has revealed crucial requirements for successful integration. The chapter has established the foundation for a successful curriculum implementation strategy by addressing these essential requirements. It acknowledges the significance of overcoming obstacles to guarantee a smooth educational experience.

The chapter has examined the key elements and curriculum implications of the Whole Brain® approach. This exploration provides educators with a thorough guide, offering insights into the fundamental elements that contribute to the overall development of learners in coding and robotics education.

The assessment of the influence of the Whole Brain® approach on the curriculum has been expanded to evaluate the development of 21st century competencies fostered by these techniques. The analysed data highlighted the transformative capacity of Whole Brain® coding and robotics techniques in enhancing the overall learning experience.

A substantial part of the chapter has been devoted to examining the impact of the backward design approach. The chapter has examined how the Whole Brain® coding and robotics framework contributes to curriculum development and affects effectiveness and engagement in education. This analysis has provided a detailed understanding of the strategic foundations that shape the educational alchemy within this framework.

To summarise, Chapter 6 provided a thorough exploration of the complexities of Whole Brain® coding and robotics education. It surpasses mere data analysis to uncover significant insights, showcasing a diverse range of challenges, opportunities and transformative nuances. As I contemplate Malcolm X's enduring sagacity, the chapter functions as a gateway to the future of education, providing a clear plan for those who aspire to create opportunities for learners to self-equip for the ever-evolving real-life challenges of the unknown future.

7. CHAPTER 7: BRIDGING THE GAP FROM THEORY TO FINDINGS

7.1 Introduction

"Research is to see what everybody else has seen and to think what nobody else has thought." Albert Szent-Györgyi (1957)

Albert Szent-Györgyi's (1957) timeless words serve as an important reminder of the fundamental purpose of research to reveal the unseen, to think beyond the ordinary, and to enrich the constantly evolving reservoir of knowledge. At this point in my doctoral trajectory, this chapter represents a crucial moment where I delve into the culmination of my journey, synthesising the discoveries, insights and recommendations gleaned from my exploration of action research principles in developing a Whole Brain® coding and robotics curriculum for Grade 4 learners.

As I navigate the intricate labyrinth of synthesising the discoveries, insights and recommendations, Szent-Györgyi's (1957) insight acts as a guiding light, urging me to look beyond the surface and seek the uncharted territories of knowledge, where the synthesis of findings and literature becomes a beacon illuminating new horizons in the scholarly landscape.

7.2 Summary of findings

In developing a Whole Brain® coding and robotics curriculum for Grade 4 learners, I encountered challenges that tested my creativity and problem-solving competencies. A significant hurdle was the lack of tablets, which hindered activities requiring digital interfaces. This challenge was exacerbated by delayed equipment delivery, impacting the curriculum's timeline. Collaboration issues among learners also posed a challenge, requiring creative solutions to ensure all learners could participate effectively in groups. However, these challenges presented opportunities to enhance the curriculum. Learners' enthusiastic curiosity and eagerness to explore the robotics sets provided a foundation for engaging what was to be mastered. By addressing these challenges and seizing these opportunities, the curriculum evolved to meet Grade 4 learners' diverse needs. Adaptations such as modifying tasks and promoting collaboration were instrumental. Observations and reflections provided valuable insights into challenges and opportunities. Scarcity of tablets and insufficient robotics sets limited access and impacted hands-on tasks to be executed. Wi-Fi connectivity issues further hindered progress. However, there were notable opportunities, including the creativity and coding competencies displayed by all groups, demonstrating the potential for meaningful learning experiences. Addressing these challenges and leveraging these opportunities refined the curriculum to better meet the needs of Grade 4 learners.

In learner interviews, additional challenges and opportunities emerged within the coding and robotics curriculum. One notable challenge was interpersonal conflicts within teams, hindering collaboration and the learning experience. These conflicts arose from differences in opinions, leadership styles or communication breakdowns, highlighting the importance of fostering positive team dynamics. Another challenge was unforeseen disturbances such as technical issues, disrupting the flow of the curriculum. Despite these challenges, significant opportunities were identified, such as promoting independent exploration among learners. Encouraging learners to explore topics of interest enhanced their curiosity and motivation. Additionally, customising the curriculum to match the aspirations of learners made the learning experience more meaningful. By addressing these challenges and capitalising on these opportunities, I created a more effective and tailored curriculum. This involved implementing strategies to improve teamwork and communication competencies, as well as providing support for independent exploration. Overall, these efforts led to a more engaging and impactful learning experience for Grade 4 learners in the coding and robotics curriculum.

The combined insights from interviews and observations in the Whole Brain® coding and robotics curriculum for Grade 4 learners highlighted several key areas for improvement. Challenges in technology accessibility, such as a lack of tablets and insufficient sets were identified as hindrances to the learning experience. Group dynamics also posed challenges, with learners struggling with collaboration and teamwork. Additionally, time management emerged as a significant challenge, with limited time impacting the depth and scope of the curriculum. Despite these challenges, there were opportunities for improvement. Promoting self-directed exploration empowered learners to take ownership of their learning and explore topics of interest more deeply. This enhanced their engagement and motivation, leading to a more meaningful learning experience. Furthermore, improving facilitation methods such as providing more guidance and support, enhanced the overall learning experience and addressed the challenges identified. By addressing these challenges and capitalising on these opportunities, I created a more effective and engaging Whole Brain® coding and robotics curriculum for Grade 4 learners. This involved implementing strategies to improve technology access, such as ensuring an adequate number of tablets and sets for all learners. Additionally, fostering a positive learning environment that encouraged collaboration and teamwork enhanced the overall learning experience. Overall, these efforts led to a more engaging and impactful learning experience for Grade 4 learners in the coding and robotics curriculum.

In the intersection of theoretical knowledge and practical application within the Whole Brain® coding and robotics curriculum for Grade 4 learners, I identified challenges in two key areas. Firstly, learners faced difficulties in rationalising their selection of prototypes, indicating a gap between theoretical understanding and practical application. This suggested a need for clearer guidelines and support to help learners make informed decisions in their design process. Secondly, ensuring uniformity in testing procedures posed a challenge, highlighting the importance of standardising assessment methods to accurately assess learners' understanding and competencies. Addressing these challenges could improve the alignment between theoretical concepts and practical implementation, enhancing the overall effectiveness of the coding and robotics curriculum.

Identifying pre-existing conditions for implementing an action research-driven Whole Brain® coding and robotics curriculum unveiled several challenges. These included reliance on my computer for coding, which limited access and hindered individual exploration. Additionally, restrictions related to tablets and sets posed obstacles, limiting hands-on learning opportunities. Conflicts within learner groups also emerged as a barrier, disrupting collaboration and hindering progress. Moreover, time limitations imposed constraints on the depth and scope of the curriculum. To address these conditions effectively, strategies were necessary to improve technology access, such as providing additional devices or allocating dedicated coding time. Conflict resolution techniques and fostering a supportive learning environment were vital for mitigating conflicts within learner groups. Additionally, efficient time management strategies were essential to optimise learning experiences and ensure comprehensive curriculum coverage. By implementing these strategies, educators could overcome pre-existing challenges and create an environment conducive to effective learning and skill development in coding and robotics for Grade 4 learners.

7.3 Limitations of the study

The study's limitations are important to consider for a thorough understanding of its scope and implications. The study's findings are limited in generalisability because they focus solely on Grade 4 learners and a specific coding and robotics curriculum. The findings of this study are beneficial for educators and researchers in similar contexts but may not be directly transferable to different educational settings or grade levels. Caution should be used when applying the findings to other contexts. What might not be considered a limitation is the fact that the scholarship of action research employed, may be imitated by any educational practitioner and extrapolated to their practice.

The study's sample size was restricted, potentially impacting the comprehensiveness and scope of the insights obtained. A larger sample size would offer a more thorough insight into the challenges and opportunities involved in implementing the curriculum. The study's narrow focus on a particular group of learners restricts the applicability of the results to a wider population. However, it is common in action research studies that sample sizes are small as one works with one's own practice and the learners enrolled – you work with what you have/what is.

The study may be subjective due to my reflections and observations. Subjectivity may impact how the findings are interpreted and the conclusions that are drawn from them. Although attempts were made to validate and ensure the reliability of the data, the researcher's subjective perspective cannot be entirely eradicated. The study's design, which includes me as the educator and the researcher, could introduce bias in data interpretation. My perspective may have influenced the analysis and interpretation of the findings, despite attempts to reduce bias through reflective practices and peer debriefing. Again, as the researcher in an action research initiative such as this study is also the practitioner, the self-regulated professional development and constructivist epistemology expects one to create own meaning.

Time constraints have affected the study, restricting the opportunity to carry out more detailed interviews or observations. A longer study period would have facilitated a more comprehensive examination of the challenges and opportunities associated with implementing the curriculum.

Resource limitations, like limited access to tablets or robotics sets, have impacted the curriculum implementation and the learners' experiences. These constraints should be considered when analysing the findings.

External factors, like alterations in the school setting or unexpected events, have impacted the study results. Although attempts were made to mitigate these factors, their influence cannot be completely disregarded.

Finally, ethical concerns, such as safeguarding learner confidentiality and welfare, have influenced the study's structure and execution. These factors are crucial for upholding the study's integrity and safeguarding the participants' rights.

Ultimately, the study offers valuable insights into the obstacles and possibilities of creating and executing a coding and robotics curriculum for Grade 4 learners. However, it is important to consider its limitations when analysing the results. Future research could overcome these limitations by increasing the sample size, conducting longer studies and taking into account a wider variety of contexts and perspectives.

7.4 Contributions of the study

This study makes a substantial contribution to the field of education by offering valuable insights into creating and executing coding and robotics curricula for Grade 4 learners. It enriches the existing literature on coding and robotics education by incorporating action research principles and Whole Brain® thinking into curriculum development. It provides a detailed framework that tackles challenges and utilises opportunities in developing and implementing successful coding and robotics programmes customised for Grade 4 learners' diverse needs.

The study's main contribution is its focus on the challenges and opportunities faced in curriculum development and implementation. It provides valuable insights for educators and curriculum developers interested in developing similar programmes by documenting the challenges and opportunities and emphasises the importance of addressing technology accessibility, group dynamics and time management. It also stresses the significance of taking advantage of opportunities to promote self-directed exploration and improve methods of facilitating and assessing learning – with a view to transforming one's entire teaching practice.

The study provides valuable insights into how the curriculum enhances learners' coding and robotics competencies and knowledge, contributing to the field. It shows how the curriculum enhances learners' creativity, collaboration and problem-solving competencies through observations, reflections and interviews. This discovery is important because it emphasises the ability of coding and robotics education to develop essential 21st century competencies in Grade 4 learners, equipping them for future challenges and opportunities in a world that is becoming more technology oriented.

The study contributes by offering a thorough curriculum that combines action research principles and Whole Brain® thinking into coding and robotics education for Grade 4 learners. The curriculum was developed and implemented through the creation of engaging learning activities, efficient resource management and resolution of challenges in practical educational environments. This contribution shows that implementing the curriculum in real-life educational settings is both possible and effective, serving as a useful authentic exemplar for educators and curriculum developers.

The study contributes theoretically by basing the curriculum development process on established educational theories and frameworks. It utilises Whole Brain® thinking and action research concepts to ensure that the curriculum is grounded in solid educational principles and has a robust theoretical foundation. This theoretical basis not only boosts the credibility and validity of the curriculum but also offers a theoretical framework that can be used in various educational settings and fields.

The study contributes methodologically by showcasing an innovative approach to curriculum development using Whole Brain® action research. The curriculum was continually improved through a systematic and iterative design process that included multiple cycles of planning, acting, observing and reflecting based on feedback and observations. This methodological approach ensured the curriculum was tailored to the needs of learners and the educator and established a structured framework for future curriculum development.

This study provides a comprehensive framework for curriculum development and implementation in the field of coding and robotics education, making significant contributions. It provides valuable insights into the challenges and opportunities of developing and implementing coding and robotics programmes for Grade 4 learners by combining action research principles and Whole Brain® thinking. The practical, theoretical and methodological contributions lay a valuable groundwork for future research and curriculum development in coding and robotics education, benefiting educators, researchers and policymakers in STEM education.

7.5 Recommendations for future research

To improve the comprehension and efficiency of coding and robotics curricula, future research can investigate various approaches. Increasing the sample size to encompass a broader spectrum of learners from different grade levels and educational backgrounds could enhance the generalisability of results. Longitudinal studies that monitor learners' advancement over time could provide valuable insights into the lasting impacts of these curricula on growth in learners' mastering of learning outcomes and competencies. Studies comparing various teaching methods, like traditional classroom instruction and project-based learning, could identify the most effective ways to teach coding and robotics to young learners. Furthermore, cross-cultural studies could investigate the customisation of coding and robotics programmes to cater to various educational environments, considering cultural variations in thinking preferences and other preferences regarding their learning to ensure enhanced learning experiences for all.

Studying the professional development and support requirements of educators teaching coding and robotics could improve program implementation. Improving educators' understanding of the challenges in incorporating coding and robotics into teaching, along with offering them proper professional development opportunities and resources, could enhance the quality of coding and robotics education. Examining the incorporation of coding and robotics with various subjects like mathematics, science and language arts may provide a comprehensive method for STEM education, promoting interdisciplinary competencies and knowledge in learners.

Studying the effects of coding and robotics programmes on learners' soft competencies like problem-solving, critical thinking, creativity and collaboration could offer a deeper understanding of the advantages of these programmes beyond just technical skill enhancement. Recognising the impact of coding and robotics education on the development of essential competencies could influence the creation and execution of upcoming programmes.

Furthermore, research that aims to enhance the accessibility and fairness of coding and robotics programmes could help alleviate inequalities in accessing these educational opportunities. Studying the obstacles encountered by marginalised groups, like girls and learners from low-income families, and creating tactics to address these obstacles could enhance the inclusivity and fairness of coding and robotics education.

Studying parental involvement in promoting coding and robotics education may provide valuable insights in engaging parents in their children's learning and supporting their interest in STEM fields. Exploring the parental role in promoting coding and robotics education could help develop methods to enhance parental involvement and backing for these initiatives.

Studying the influence of coding and robotics education on learners' career readiness could offer valuable insights into how these programmes can equip learners for future STEM careers. Recognising the competencies acquired from coding and robotics education that are highly sought after by employers could help shape future educational policies and practices focused on equipping learners for the job market.

7.6 Conclusion

This thesis has investigated the development and implementation of a Whole Brain® coding and robotics curriculum for Grade 4 learners, incorporating action research principles. The study has made a significant contribution to the field of education by offering valuable insights into the challenges and opportunities of developing and implementing such a curriculum. This study provides a detailed framework for educators and curriculum developers by documenting challenges like technology accessibility, group dynamics and time management, and suggesting opportunities for curriculum enhancement such as promoting self-directed exploration and improving methods of facilitating learning.

The study has shown that the curriculum enhances learners' coding and robotics skills and knowledge, positively impacting their creativity, collaboration and problem-solving abilities through observations, reflections and interviews. It emphasises the significance of coding and robotics education for Grade 4 learners in developing essential 21st century skills to equip them for future real-life challenges and opportunities in a technology-driven society.

The study has contributed by creating a thorough curriculum that combines action research principles and Whole Brain® thinking to tackle challenges and make the most of opportunities. The curriculum development process is based on established educational theories and frameworks, ensuring that the curriculum is guided by solid educational principles and has a strong theoretical foundation.

The study has contributed methodologically by showcasing an innovative approach to curriculum development using action research. The systematic and iterative design process has facilitated the continuous enhancement of the curriculum through feedback and observations, serving as a valuable model for future curriculum development endeavours.

This thesis has made substantial contributions to the coding and robotics education field, offering a valuable framework for educators, researchers and policymakers in STEM education. This study has advanced the field by tackling challenges and utilising opportunities to develop and implement a Whole Brain® coding and robotics curriculum for Grade 4 learners, laying the groundwork for future research and curriculum development.

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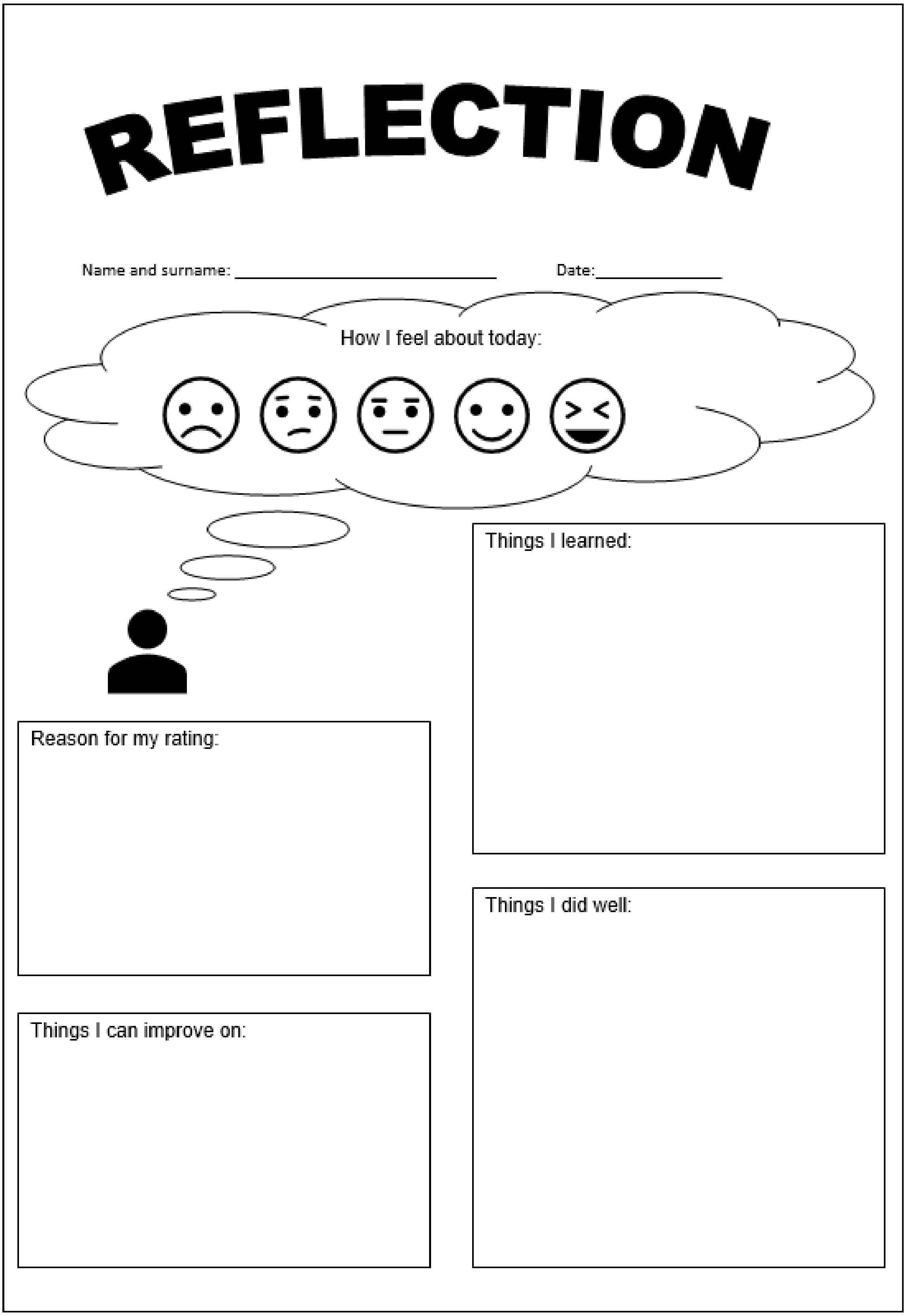
Appendix A

Feedback forms



REFLECTION

Name and surname: ______________________ Date: __________

How I feel about today:

Things I learned:

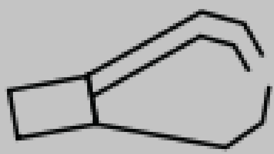
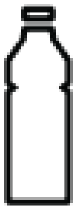
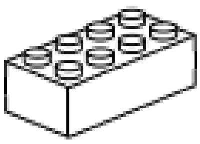
Reason for my rating:

Things I did well:

Things I can improve on:

Appendix B

Grabber worksheets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	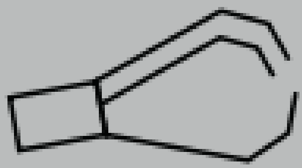	
		
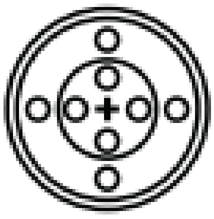		
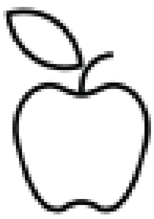		
=		

Appendix C

Learner reflection worksheet

Robotics

Peer assessment

Name and surname of the team member you are grading:

____

Class: ________________

Read the following conditions carefully and tick the block that you agree with the most.

	Yes	No
Communication: • Listen carefully and talk with your team • Say what you mean in a clear way • Be nice when you talk to your team • Always ask questions and fix any problems with talking		
Collaboration: • Help the team reach its goals and do your tasks • Be ready to find solutions together and agree on things • Share the jobs fairly and help your team when they need it • Stay happy and be kind to everyone in your team, no matter how different they are		
Accountability: • Do your own tasks and finish what you say you'll do • Be someone others can count on in the team • Make sure you do your part to help the team succeed • If there are problems, try to fix them without waiting for someone else to do it		
Overall contribution: • Always try your best to help the team do well • Be a good part of the team and make it a happy place • Work hard and stay focused on what the team wants to achieve • Don't do things that make the team do worse or feel unhappy		
Total:		

Appendix D

Rubric for Assessing Engineering, Coding, and Critical Thinking Competencies

Assessment criteria	3: Advanced	2: Proficient	1 : Developing
Ability to Apply Engineering and Design Competencies	Applies engineering and design principles effectively, demonstrating creativity and innovation	Applies engineering and design principles with some effectiveness	Demonstrates basic understanding of engineering and design concepts
Coding Proficiency	Demonstrates advanced coding skills, creating complex programs	Uses coding concepts to solve problems independently	Demonstrates basic coding skills with guidance
Critical Thinking and Problem-Solving	Applies critical thinking to complex problems, developing innovative solutions.	Analyses problems and generates viable solutions.	Identifies problems but struggles with solutions.
Environmental Awareness	Integrates environmental considerations into solutions.	Demonstrates awareness of environmental impact in design and coding.	Shows basic understanding of environmental issues.
Teamwork and Collaboration	Leads and contributes significantly to team projects.	Collaborates effectively with peers, sharing	Works independently with minimal interaction.

		ideas and responsibilities.	
Presentation Competencies	Engages audience, demonstrating strong presentation skills.	Delivers clear and organized presentations.	Presents information with minimal structure and clarity.
Integration of Technology:	Demonstrates advanced use of technology to enhance outcomes.	Integrates technology effectively into projects.	Uses technology to complete tasks.
Iterative Design Process:	Utilizes iterative design process to refine solutions significantly.	Implements iterative improvements based on feedback.	Follows a basic design process.
Creativity and Innovation:	Demonstrates exceptional creativity and innovation.	Shows creativity in approach and solutions.	Demonstrates limited creativity in projects.
Time Management:	Demonstrates excellent time management skills, consistently meeting deadlines.	Manages time well, meeting most deadlines.	Struggles to manage time effectively.
Total:			30

Appendix E

Letter of invitation to the principal

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education

Dear Sir/Madam,

REQUEST FOR YOUR SCHOOL TO PARTICIPATE IN AN INTERVIEW AND OBSERVATION IN A RESEARCH PROJECT:

Title: Whole Brain® thinking action research in a coding and robotics curriculum for Grade 4

My name is Soené Botha. I am currently enrolled for a Doctor's degree at the University of Pretoria under the supervision of Dr Maryke Mihai and Prof. Pieter du Toit.

The aim of the study is to develop a coding and robotics curriculum for grade 4 learners. Part of the data collection for this study is interviews with learners, educators and classroom observations regarding their use of, and experience of the use of such technology.

The interview with the learners and educators will take approximately 40 minutes outside of normal teaching time per teacher and learner. The classroom observation will take place during teaching time. During this time, I will observe the teacher and learners using technology for teaching and learning.

I request your permission to allow the learners and educators to:

1. Participate in the interview; and
2. Be part of the classroom observation.

All participation is voluntary. No harm or injury will come to the educators or learners during the interview and classroom observation. Please note that the decision for the educators and learners to participate is voluntary and this will not affect his or her studies or career. None of the results obtained during the interview will be used for assessment purposes. The educators and learners will be free to request to leave the interview or observation session at any time without any explanation or consequences. In the event of a learner deciding not to be part of the classroom observation, arrangements will be made with another teacher for this learner to be under supervision during this time.

I would also like to inform you that I will be audio recording the interviews and observations for research purposes. The purpose of the audio recording is to capture and transcribe the data accurately. All information obtained during the research study will be treated confidentially. My supervisor and I will have access to the data. No names of the learners, educators or school will be mentioned during reporting in the study. Pseudonyms will be used to avoid identification of the learner, teacher and school.

At the end of the study, you will be provided with a copy of the research report containing both the findings of the study and recommendations.

I would also like to request your permission to use the data, confidentially and anonymously, for further research purposes, as the data sets will be the intellectual property of the University of Pretoria. Further research may include secondary data analysis and use of the data for teaching purposes. The confidentiality and privacy applicable to this study will be binding on future research studies.

Thanking you in anticipation.

Soene Botha

S. Botha

Student Researcher

University of Pretoria

soenebotha@gmail.com

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Faculty of Education
Fakulteit Opvoedkunde
Lefapha la Thuto

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:

Whole Brain® thinking action research in a coding and robotics curriculum for Grade 4

I, ____,(your name) the principal of ____________________________________

TICK ONLY ONE BLOCK

give consent ☐

do not give consent ☐

to allow my school to participate in the above-mentioned study introduced and explained to me by Ms. Soené Botha, currently a student enrolled for Doctor's degree at the University of Pretoria.

I further declare that I understand, as explained to me by the researcher, the aim, scope, and purpose of collecting information proposed by the researcher, as well as how the researcher will attempt to ensure the confidentiality and integrity of the information she collects.

______________________________ ______________________

Full name Signature

____

Date

School stamp

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University of Pretoria, Private Bag X20
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Faculty of Education
Fakulteit Opvoedkunde
Lefapha la Thuto

Appendix F

Letter of invitation to the educator participants:

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education

Dear Sir/Madam,

REQUEST TO PARTICIPATE IN AN INTERVIEW AND OBSERVATION IN A RESEARCH PROJECT:

Title: Whole Brain® thinking action research in a coding and robotics curriculum for Grade 4

My name is Soené Botha. I am currently enrolled for a Doctor's degree at the University of Pretoria under the supervision of Dr Maryke Mihai and Prof Pieter du Toit.

The aim of the study is to develop a coding and robotics curriculum for grade 4 learners. Part of the data collection for this study is interviews with learners, educators and classroom observations regarding their use of, and experience of the use of such technology.

The interview with you will take approximately 40 minutes outside of normal teaching time. The classroom observation will take place during teaching time. During this time, I will observe you and your learners using technology for teaching and learning.

I request your permission to:

1. Participate in the interview; and

2. Be part of the classroom observation.

All participation is voluntary. No harm or injury will come to you during the interview and classroom observation. Please note that the decision for you to participate is voluntary. None of the results obtained during the interview will be used for assessment purposes. You will be free to request to leave the interview or observation session at any time without any explanation or consequences.

I would also like to inform you that I will be audio recording the interviews and observations for research purposes. The purpose of the audio recording is to capture and transcribe the data accurately. All information obtained during the research study will be treated confidentially. My supervisor and I will have access to the data. No names of the learners, educators or school will be mentioned during the reporting phase of this study. Pseudonyms will be used to avoid identification of the learner, teacher and school.

At the end of the study, you will be provided with a copy of the research report containing both the findings of the study and recommendations.

I would also like to request your permission to use the data, confidentially and anonymously, for further research purposes, as the data sets will be the intellectual property of the University of Pretoria. Further research may include secondary data analysis and use of the data for teaching purposes. The confidentiality and privacy applicable to this study will be binding on future research studies.

Thanking you in anticipation.

Soene Botha

S Botha

Student Researcher

University of Pretoria

soenebotha@gmail.com

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UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education

LETTER of CONSENT

INDIVIDUAL PARTICIPANT

VOLUNTARY PARTICIPATION IN THE RESEARCH PROJECT ENTITLED:

Whole Brain® thinking action research in a coding and robotics curriculum for Grade 4

I, ____, (your name)

TICK ONLY ONE BLOCK

give consent ☐

do not give consent ☐

to participate as an individual in the above-mentioned study introduced and explained to me by Ms Soené Botha, currently, a student enrolled for a Doctor's degree at the University of Pretoria.

The researcher has explained the aim of this study, its scope and purpose. Data collection methods proposed by the researcher have been outlined and clearly explained as well as how she will ensure confidentiality and the authenticity and integrity of the information.

______________________________ ____________________

Full name Signature

____

Date

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Appendix G

Letter of invitation to the parents or guardians of learner participants:

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education

Dear Sir/Madam,

REQUEST FOR YOUR CHILD TO PARTICIPATE IN AN INTERVIEW AND OBSERVATION IN A RESEARCH PROJECT:

Title: Whole Brain® thinking action research in a coding and robotics curriculum for Grade 4

My name is Soené Botha. I am currently enrolled for a Doctor's degree at the University of Pretoria under the supervision of Dr Maryke Mihai and Prof Pieter du Toit.

The aim of the study is to develop a coding and robotics curriculum for grade 4 learners. Part of the data collection for this study is interviews with learners, educators and classroom observations regarding their use of, and experience of the use of such technology.

The interview with your child will take approximately 40 minutes outside of normal teaching time. The classroom observation will take place during teaching time. Your child will also be part of the classroom observation.

I request your permission to allow your child to:

1. Participate in the interviews; and
2. Be part of the classroom observation.

Your child's participation is voluntary. No harm or injury will come to your child during the interview and classroom observation. Please note that the decision for your child to participate is voluntary and this will not affect his or her studies. None of the results obtained during the interview will be used for assessment purposes. Your child will be free to request to leave the interview or observation session at any time without any explanation or consequences. In the event that your child decides not to be part of the classroom observation, arrangements will be made with the school for your child to be under supervision during this time.

I would also like to inform you that I will be audio recording the interviews and observations for research purposes. The purpose of the audio recording is to capture and transcribe the data accurately. All information obtained during the research study will be treated confidentially. My supervisor and I will have access to the data. No names of the learners, educators or school will be mentioned during the reporting phase of the study. Pseudonyms will be used to avoid identification of the learner, teacher and school.

At the end of the study, you will be provided with a copy of the research report containing both the findings of the study and recommendations.

I would also like to request your permission to use the data, confidentially and anonymously, for further research purposes, as the data sets will be the intellectual property of the University of Pretoria. Further research may include secondary data analysis and use of the data for teaching purposes. The confidentiality and privacy applicable to this study will be binding on future research studies.

Thanking you in anticipation.

Soene Botha

S Botha

Student Researcher

University of Pretoria

soenebotha@gmail.com

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UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education

PARENTAL CONSENT FORM FOR CHILD PARTICIPATION IN RESEARCH

VOLUNTARY PARTICIPATION IN THE RESEARCH PROJECT ENTITLED:

Whole Brain® thinking action research in a coding and robotics curriculum for Grade 4, ____, name of parent

TICK ONLY ONE BLOCK

Give consent ☐

Do not give consent ☐

for my child _____________________________________(name of child) to participate in the semi structured interview and observation of my research study.

_________________________________ ______________________

Parent / Guardian full name Signature

____

Date

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Appendix H

Letter of invitation to the learner participants:

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education

Dear student,

INVITATION TO PARTICIPATE IN A RESEARCH PROJECT:

Whole Brain® thinking action research in a coding and robotics curriculum for Grade 4

What is educational research?

Educational research is something we do to find new knowledge about the way people learn. We use research projects or studies to help us find out more about ways to improve educational practices.

What is this research project all about?

This project wants to develop a coding and robotics curriculum.

Who is doing the research?

The project is being done by Ms Soené Botha, who is at the moment enrolled for a Doctor's degree at the University of Pretoria. One of the requirements to complete this degree is to complete an educational research project that will help improve educational practices.

What will happen to me in this study?

During this study, you will have the opportunity to develop 21st century competencies through coding and robotics. You will also have the opportunity to explain the competencies you would like to develop during the coding and robotics programme, the content you would like to be covered during the programme, and the challenges and positive experiences you and your teacher experienced during the programme.

Can anything bad happen to me?

There are no risks if you should agree to take part in the study.

Can anything good happen to me?

It is possible that, by doing this interview, you will have a greater understanding of how technology can support you in your learning and how technology can minimise the barriers that you experience. Please take note that this participation will not affect your grades or studies. You will also not receive any incentives.

Will anyone know I am in the study?

Everyone's responses and answers to the activities will be kept confidential and it will not be discussed with other educators or learners. While your thoughts and ideas on the intervention will form part of the results of the study, your name will not be shared with anybody from the school, or the University of Pretoria and you will, therefore, be anonymous.

What if I do not want to do this?

You are not forced to take part in the research project, even if your parents give their consent for you to take part. You are allowed to withdraw from the study at any stage.

What will happen when the study is done?

At the end of the study, you will receive a copy of the study that you may read to gain more knowledge in the use of technology to help you overcome your barriers.

I would also like to request your permission to use your data, confidentially and anonymously, for further research purposes, as the data sets will be the intellectual property of the University of Pretoria. Further research may include secondary data analysis and the use of the data for teaching purposes. The confidentiality and privacy applicable to this study will be binding on future research studies.

Thank you for being willing to consider this invitation to participate in the research project.

Yours in service of education,

Soene Botha

S Botha

Student Researcher

University of Pretoria

soenebotha@gmail.com

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UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education

ASSENT FORM FOR PARTICIPATION IN RESEARCH

VOLUNTARY PARTICIPATION IN THE RESEARCH PROJECT ENTITLED:

Whole Brain® thinking action research in a coding and robotics curriculum for Grade 4

I, (your name and surname)

TICK ONE BLOCK

give consent	☐
do not give consent	☐

to take part in the interviews and the classroom observation that is being done by Ms Soené Botha.

I understand what the study is about and what I will be doing when taking part in the study.

I am taking part because I want to. I have been told that I can stop my participation at any time I want to and nothing will happen to me if I want to stop.

____________________________ ____________________________

Your full name Signature

____

Date

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Appendix I

Leaner interview questions:

Learner pre-interview questions

Demographic information:

1. Age:
2. Gender:
3. Grade:
4. How long have you been taking coding and robotics at this school?

If learner has previous experience with coding and robotics:

4.1 What challenges did you experience in the classroom previously?

______

______

4.2 What challenges do you think the educator (teacher) experienced previously?

______

______

4.3 What do you think you should do differently to ensure you do not experience the same challenges?

______

______

4.4 What would you like the educator (teacher) to do differently to ensure you do not experience the same challenges?

______

______

5. What competencies would you like to learn in this class?

6. Do you think these competencies will be valuable in the future? Why?

7. What technology would you like to use in this classroom?

8. How would you like the educator to teach you? Which strategies should be used?

9. What assessment opportunities do you think should be created?

Learner post interview questions

1. What challenges did you experience in the classroom?
2. What challenges do you think the educator (teacher) experienced?
3. What do you think you should do differently to ensure you do not experience the same challenges?
4. What would you like the educator (teacher) to do differently to ensure you do not experience the same challenges?
5. How did the educator teach you?
6. Explain the progress of a lesson.
7. What would you add to the lessons to make the work easier for you to understand?
8. What competencies did you acquire during this class?
9. Do you think these competencies will be necessary in the future? Why?

10. What other competencies would you have liked to acquire?

11. What assessment strategies have been used? Do you think these strategies are beneficial for your development in coding and robotics?

Appendix J

Observation form:

Observation schedule for classroom observations (fieldnotes)

1. Challenges that learners experience

2. Challenges that the educator experience

3. Positive learner experiences

4. Positive educator experiences

5. Pedagogical strategy used

6. Action research principles used

___

___

7. 21st Century competencies being developed

___

___

8. Appropriateness of assessment strategies

___

___

9. Outcomes reached

___

___

10. Outcomes not reached

___

___

___

___