Chapter Seven: Revolutionising Coding and Robotics Curriculum Design for Grade 4 trough Whole Brain® Thinking and Action Research

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Introduction and background

The Fourth Industrial Revolution (4IR), represents a significant shift in the global economy and society, fuelled by the integration of advanced digital technologies. As traditional jobs evolve, there is an increasing demand for twenty-first century competencies. The twenty-first century competencies, referred to as the 4Cs, encompass communication, cooperation, critical thinking and creativity, as advocated by Reaves (2019) and Thornhill-Miller et al. (2023). Scholars argue that coding and robotics education can help learners develop these critical twenty-first century competencies, making it an essential component of modern education (Kálózi-Szabó et al. 2022).

The school's journey toward incorporating coding and robotics as a subject began as a co-curricular offering in 2022. Initially, coding and robotics were presented as an extracurricular activity, allowing learners to voluntarily engage with the subject outside regular class time once a week for an hour. As interest in the co-curricular programme grew, the school recognised the need to integrate coding and robotics into the mainstream curriculum. This shift ensured that all learners could take part in the curriculum. The formal adoption of coding and robotics as a subject represented a significant progress in the school's educational approach, reinforcing not only technical competencies, but also essential twenty-first century competencies. This aligns with the broader global context, where

4IR technologies are reshaping economies and societies (Butler-Adam 2018; Schwab 2017; Sutherland 2020).

To bridge the gap in the national coding and robotics curriculum for a private school, we began developing a tailored coding and robotics curriculum that was aligned with both the learners' current abilities and the competencies they needed to learn. Recognising these gaps prompted the need for a Whole Brain® curriculum.

A Whole Brain® curriculum is an educational approach based on Whole Brain® thinking. Whole Brain® thinking posits that individuals have four distinct modes of thinking, culminating in practical, relational, organisational and experimental thinking preferences, respectively (Herrmann Global LLC 2022). By focusing on all four modes of thinking, this curriculum aims to improve learners' mastering of learning outcomes. Additionally, it focusses on holistic development by encouraging the 4Cs, allowing learners to maximise their full potential. Ultimately, this approach not only prepares learners for future challenges in a rapidly evolving technological landscape, it also supports their overall development as innovative and adaptive learners.

Research focus

Considering the evolving educational technology landscape and the need to design learning opportunities in which learners can be challenged by engaging in relevant learning experiences, the current study addresses 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?

This study explored the following secondary research questions:

- What pre-existing conditions are necessary 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 does the Whole Brain® approach enhance the quality of the coding and robotics curriculum for Grade 4 learners?

- To what extent does the backward design approach contribute to the development of an effective and engaging coding and robotics curriculum for Grade 4 learners?

Literature review

The impact of the 4IR on education

The integration of coding and robotics into education has become increasingly significant in recent years, driven by the rapid technological advancements associated with the 4IR. Although its full impact remains uncertain due to its early developmental stage, researchers like Reaves (2019), Kayembe and Nel (2019) and Carrim (2022) emphasise its significant impact on education.

The rapid advancement of technology presents a continuous challenge for schools, particularly those with constrained financial resources (Kayembe and Nel 2019). Schools require modernised infrastructure and training to effectively incorporate new technologies. However, disparities exist between schools with access to advanced technology and those without, creating challenges in implementing coding and robotics curricula effectively.

Educational policies, curricula and pedagogical approaches must adapt to equip learners with competencies relevant to the 4IR. Technical skills, such as coding, robotics and data analysis are crucial for preparing learners for a workforce that values interdisciplinary collaboration and flexible, project-based work (Kayembe and Nel 2019). Furthermore, interdisciplinary learning in coding and robotics can prompt learners to integrate knowledge across various subjects, which is essential for addressing complex, interconnected challenges in their professional careers (Sun et al. 2024).

To ensure education remains pertinent and effective in a technology-driven landscape, educators and institutions must balance leveraging the advantages of technology with mitigating potential drawbacks. By fostering twenty-first-century competencies, such as critical thinking, problem-solving and digital literacy, educational institutions can better prepare learners for success in the dynamic and evolving landscape of the 4IR.

Coding and robotics

The integration of technology in education is increasingly evident through the growing presence of coding and robotics in the curriculum (LEGO® Education 2022). Educational robots, or programmable toys, support tactile learning and help learners develop problem-solving and critical thinking skills through active engagement (Gunes and Kucuk 2022).

Various tools are used in classrooms, such as Bee-Bots for early sequencing skills, LEGO® kits for construction-based problem-solving and Arduino boards for hands-on electronics and programming experience.

Coding is a core competency in the digital age, empowering learners to create software, apps and websites. Block-based coding—using drag-and-drop visual elements—introduces programming concepts without requiring complex syntax, allowing learners to focus on logical reasoning and computational thinking (Sun et al. 2024).

Twenty-first century competencies

The twenty-first century demands a blend of traditional and technological competencies to ensure learners are prepared for dynamic professional and personal environments (Thornhill-Miller et al. 2023). Central to this shift are the 4Cs—critical thinking, communication, collaboration and creativity—which align closely with curriculum goals and Whole Brain® learning principles.

Critical thinking and problem-solving support informed decision-making in complex situations. Communication fosters clarity, active listening and understanding diverse perspectives. Collaboration develops teamwork, negotiation and shared accountability. Creativity enables innovation and adaptability in an ever-changing world.

Embedding the 4Cs into teaching and learning equips learners with essential, future-oriented competencies and supports holistic cognitive development through Whole Brain® strategies.

Application of the Whole Brain® Thinking Model in education

The Whole Brain® thinking model posits that individuals exhibit preferences for cognitive processes across four quadrants: A, B, C and D. The quadrants represent analytical, practical, relational and experimental thinking, respectively. This curriculum development model recognises the necessity of addressing all cognitive domains, fostering holistic learning opportunities.

In the field of curriculum development, it is essential to acknowledge and accommodate these diverse cognitive preferences. Individuals identified as analytical thinkers (quadrant A) exhibit proficiency in tasks requiring logical reasoning and problem-solving (Herrmann Global LLC 2022). Practical thinkers (quadrant B) excel in hands-on and applied activities (Herrmann Global LLC 2022). Individuals who conceptualise through relationships (quadrant C) may gain advantages from participating in collaborative and interpersonal learning experiences, whereas those who adopt an experimental mindset (quadrant D) may seek out creative and innovative approaches to understanding concepts (Herrmann Global LLC 2022).

In summary, the incorporation of Whole Brain® thinking into curriculum design provides a versatile and efficient method to engage learners by aligning with their preferred cognitive styles.

Developing twenty-first century competencies through Whole Brain® thinking

The twenty-first century has ushered in profound shifts in how we live, learn, and work—requiring an expanded set of competencies that blend traditional skills such as critical thinking and communication with emerging technological proficiencies (Thornhill-Miller et al. 2023). These competencies are not only essential for career readiness, they are equally critical for personal growth and meaningful participation in a complex, digital society.

To remain relevant, education must deliberately cultivate these competencies through curriculum design. Learners must be able to think critically, solve problems, communicate effectively, collaborate in diverse teams and adapt to change. In digitally rich environments, proficiency with technology is no longer optional—it underpins most forms of communication, collaboration and innovation (Kayembe and Nel 2019).

Whole Brain® thinking offers a holistic framework to support the development of these competencies. It acknowledges that individuals engage with the world through different cognitive preferences—analytical, sequential, interpersonal and imaginative. By designing learning experiences that tap into all four quadrants of the brain, educators can promote deeper understanding, creativity and flexible thinking. This approach aligns well with the aims of twenty-first century education: to prepare learners not just to absorb information, but to apply knowledge across disciplines, solve real-world problems and continue learning throughout life.

Integrating Whole Brain® thinking into curriculum development ensures that learners are not only equipped with the necessary skills for the digital age, they are also cognitively and emotionally prepared to thrive in dynamic and uncertain environments. It encourages personalised, inclusive learning that fosters both competence and confidence—hallmarks of the future-ready learner.

Relevance of Whole Brain® curriculum development in coding and robotics

The integration of twenty-first-century competencies in coding and robotics education is essential for preparing learners for a fast-evolving, technology-driven world. The Whole Brain® curriculum development construct offers a holistic, structured framework that supports competency-based learning across all phases of curriculum design and delivery.

In the assessment phase, analytical tools are used to gauge learners' current skills and identify gaps, ensuring alignment with targeted competencies. The design phase focuses on setting clear learning outcomes and objectives, using approaches like backward design to align teaching strategies with desired skills in problem-solving, critical thinking and technological fluency.

During development, materials and tasks are created to foster collaboration, engagement and interdisciplinary learning—supporting both cognitive and interpersonal growth. Feedback mechanisms at this stage ensure that curriculum content remains relevant and inclusive. The implementation phase encourages active exploration and innovation, promoting creativity and adaptability in digital learning environments such as coding and robotics.

Finally, evaluation and iteration draw on all quadrants of Whole Brain® thinking, ensuring that reflection and feedback lead to continuous curriculum refinement. This dynamic cycle not only strengthens content delivery, it also enhances learners' resilience, self-directed learning and readiness for complex challenges.

By aligning curriculum development stages with Whole Brain® thinking and twenty-first-century competencies, educators can cultivate well-rounded learners equipped for the demands of the digital age.

National curriculum context: Coding and robotics in South Africa

South Africa's integration of coding and robotics into the national curriculum reflects a strategic effort to align with global technological trends and reduce digital inequality. Grounded in the goals of the National Digital and Future Competencies Strategy (South African Government 2020), this initiative supports Sustainable Development Goal 4 by promoting equitable access to quality education and digital skills. The Department of Basic Education (DBE 2021a, 2021b) developed the curriculum as part of a broader national effort to equip learners with the competencies required for active participation in a digital economy, addressing persistent disparities in information and communications technology (ICT) access (Greyling 2022).

Curriculum development began in 2019, with a structured progression across schooling phases. Foundation Phase learners (Grades R–3) are introduced to basic coding concepts and logical sequencing. Intermediate Phase learners (Grades 4–6) engage with block-based programming (for example, Scratch), while Senior Phase learners (Grades 7–9) advance to text-based programming and robotics systems (DBE 2021b). Following initial planning in 2017 and presidential endorsement in 2019, pilot programmes launched in over 1 200 schools. The pilot phase ran from

2021 to 2023, with phased national implementation ongoing through 2025 (Liebenberg 2023). External organisations like RESA and RoboCup Junior SA have supported this rollout by fostering learner engagement through robotics competitions reinforcing the development of problem-solving and collaborative skills aligned with twenty-first-century learning goals.

Challenges of implementation in South Africa

Despite progressive curriculum reforms, the effective implementation of coding and robotics in South African schools faces persistent systemic barriers. Chief among these are limited teacher preparedness and insufficient training, with many educators lacking both the confidence and support to adopt unfamiliar pedagogies (Greyling 2022). A reluctance to shift from traditional methods further compounds the issue (Greyling 2022; Liebenberg 2023). Infrastructure shortfalls—particularly the scarcity of ICT equipment and internet access in under-resourced schools—underscore the digital divide (Liebenberg 2023). Financial constraints remain a major hurdle, as limited school budgets and inadequate state funding hinder the acquisition of essential technologies and personnel (Freese 2021). Addressing these challenges requires a coordinated national strategy focused on teacher capacity-building, equitable resourcing and sustained investment in digital infrastructure.

Construct frame

To address the evolving demands of twenty-first-century education, this study proposes a Whole Brain® Coding and Robotics Curriculum Development Model (Figure 7.1). The framework is informed by Stenhouse's (1975) curriculum-as-process paradigm, backward design, action research and Whole Brain® thinking. It synthesises cognitive diversity with iterative, evidence-based curriculum planning to ensure relevance, coherence and adaptability. The six-stage model—Assessment, Design, Development, Implementation, Evaluation and Reflection—guides a structured, yet flexible process that aligns pedagogy with learners' needs and systemic educational goals.

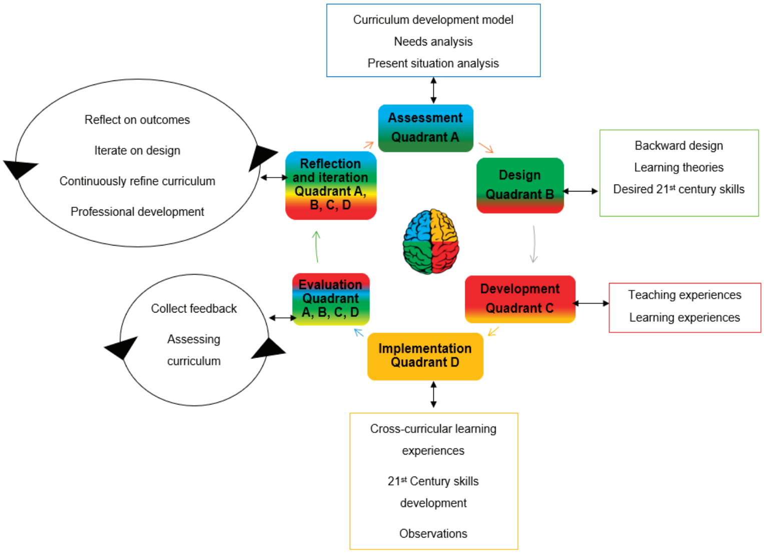

Figure 7.1: Curriculum development construct frame

Assessment (Quadrant A: Analytical thinking)

The assessment step emphasises the formulation of clear learning objectives and outcomes, which are crucial for efficient curriculum development. Essential elements encompass the selection of a suitable curriculum development model, exemplified by Stenhouse (1975), the identification of essential learning theories and the execution of a needs and situational analysis to assess the existing condition of coding and robotics education. This phase entails recognising deficiencies and opportunities for enhancement to guarantee the curriculum's relevance and efficacy. Assessments of learners are essential for customising the curriculum to address certain needs and competencies.

Design (Quadrant B: Practical thinking)

The design step emphasises the creation of a systematic curriculum that cohesively incorporates coding and robotics principles. A backward design methodology is employed, starting with the determination of required learner competencies via an analysis of needs (Knowledge Base 2021). This strategy subsequently guides the creation of educational programmes designed to cultivate these competencies (Emory 2014). Ultimately, assessment procedures are designed to measure the degree to which learners have attained the specified competencies (Emory 2014).

Development (Quadrant C: Relational thinking)

The development step includes the production of accessible and engaging educational materials and tools for educators and learners alike. Employing the backward design methodology guarantees coherence with defined learning objectives and outcomes. Creating interdisciplinary links between coding, robotics and other disciplines promotes cross-curricular education and strengthens essential competencies. This step also fosters an environment conducive to developing twenty-first-century competencies, such as critical thinking, communication, teamwork and creativity (Thornhill-Miller et al. 2023). Moreover, tactics that promote cooperation and teamwork improve the learning environment, equipping learners for real-world problem-solving in a dynamic technology context.

Implementation (Quadrant D: Experimental thinking)

The implementation step entails executing the curriculum in educational environments, maintaining coherence with learning objectives while promoting the development of twenty-first-century competencies. This step also involves observations, which are essential for evaluating curriculum efficacy and making necessary modifications to enhance educational experiences and skill acquisition.

Evaluation (Consolidation of all quadrants)

Assessing the curriculum's effect on learners' coding and robotics competencies is essential. Evaluating its efficacy in fostering Whole Brain® thinking ensuring that the programme meets the comprehensive needs of learners. Utilising feedback and empirical data to improve the curriculum increases its relevance and effectiveness.

Reflection and iteration (Synthesis of all quadrants)

Evaluating curriculum implementation results, incorporating feedback from learners and results from fieldnotes, enables the recognition of areas needing enhancement. Iterative revision informed by reflection improves curricular efficacy and alignment with learners' requirements. Modifying the curriculum to align with emerging educational trends and technology innovations guarantees its viability and enduring influence. This necessitates ongoing professional development for educators to stay informed about developing advances.

In summary, the Whole Brain® Curriculum Development Construct Frame offers a thorough and integrative methodology for a coding and robotics curriculum informed by action research. This paradigm strengthens learners' cognitive competencies by integrating analytical, practical, relational and experimental thinking, hence, preparing learners for future challenges in coding and robotics instruction. This frame highlights the relationships among curriculum creation, needs analysis, backward design, twenty-first-century competences, learning theories and professional development. It promotes a methodical and learner-centred methodology for curriculum development, catering to the evolving requirements of twenty-first century learners while encouraging innovation, adaptation and lifelong learning.

Methodological approach

This study developed an action research-driven curriculum design model to create the Whole Brain® coding and robotics curriculum for Grade 4. Illustrated in Figure 7.2, the model includes three interconnected phases: comprehensive needs analysis; backward design approach and action research, all contributing to a dynamic and transformative curriculum that meets learners' diverse needs. Each phase is described in detail below, explaining how it contributes to the Whole Brain® coding and robotics curriculum for Grade 4.

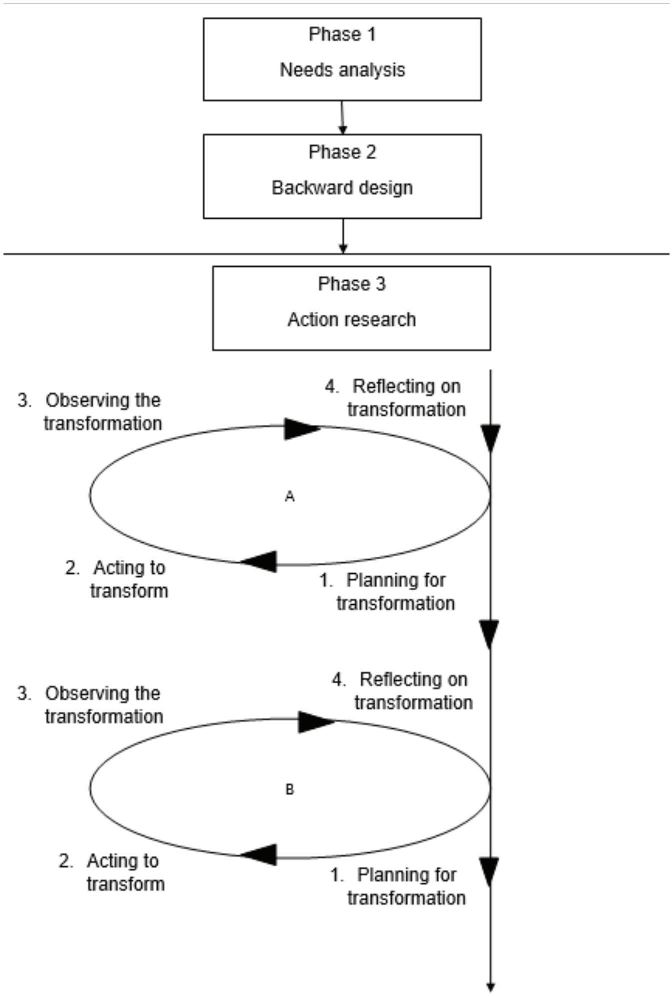

Figure 7.2: Curriculum development plan
Source: Author's own

Phase 1 of the curriculum development encompassed a thorough needs analysis, assessing learner thinking preference profiles, educator thinking preference profiles and the learning environment. Zohoorian (2015) asserts that it encompasses the examination of learners' backgrounds, competencies, deficiencies and cognitive abilities. This evaluation encompassed educator qualifications, experience, pedagogical methods, professional development requirements, adaptability to innovative approaches as well as the educational context and socio-economic influences.

Phase 2 employed the backward design approach, aligning twenty-first-century competencies and Whole Brain® thinking with suitable assessments and learning opportunities (Emory 2014; Knowledge Base 2021). This model transitions from conventional instructional design to a more comprehensive "means of facilitating learning", which includes the development of instructional materials, learning objectives, assessments and environments to enhance teaching and learning experiences.

Phase 3 executed action research, a cyclical methodology for ongoing curriculum enhancement involving planning, implementation, observation and reflection (McNiff 2016).

Results and reflections of a Whole Brain® Grade 4 coding and robotics curriculum

The implementation of the Whole Brain® Grade 4 coding and robotics curriculum followed fourteen action research cycles over six months. These cycles explored a range of cognitive, technical and collaborative competencies. Through continuous reflection and adjustment, the curriculum evolved to better align with learners' needs and the Whole Brain® model. Key themes that emerged are discussed below.

Theme 1: Building technological fluency

Learners progressively developed confidence in block-based programming using LEGO® Spike Prime™. Early cycles focused on foundational tasks such as turning on the hub and connecting motors and sensors. As learners grew more proficient, tasks became increasingly complex—integrating loops, sequences and sensor-based responses to navigate mazes and perform interactive tasks. These activities strengthened learners' analytical and experimental thinking.

Theme 2: Design thinking and prototyping

Learners engaged in iterative design and prototyping processes, applying practical and relational thinking. They built and tested grabbers, mini cars and interactive objects, refining their prototypes through peer feedback and teacher guidance. Reflection activities helped learners evaluate their designs' effectiveness, troubleshoot mechanical flaws and iterate accordingly.

Theme 3: Collaboration and communication

Group-based tasks required learners to plan collaboratively, assign roles and share tools and ideas. Learners often worked in pairs or small groups to solve problems and build interactive projects. Organising LEGO® components, maintaining shared workspaces, and jointly presenting projects all fostered interpersonal competencies aligned with the Whole Brain® relational and practical quadrants.

Theme 4: Creativity and integration

Final projects required learners to integrate coding, design and sustainability principles by building interactive pets or mini golf courses using both LEGO® and recyclable materials. These culminating tasks drew on all four thinking quadrants, encouraging learners to apply what they had learned in a cohesive, creative and authentic manner.

Key findings and curriculum impact

The implementation of the Whole Brain® coding and robotics curriculum revealed key insights into learner engagement, curriculum responsiveness and the practical application of educational theory in a primary school setting. These findings respond directly to the research questions and point to broader implications for future curriculum design.

Theme 1: Preconditions for implementation

Successful implementation relied on three core enablers: (1) access to appropriate technology (for example, tablets and LEGO® Spike Prime™

kits); (2) a flexible timetable structure that allowed for iterative design work and (3) a school culture that embraced innovation. Importantly, the use of thinking preference profiles helped tailor support for both learners and educators, reinforcing inclusivity and differentiation.

Theme 2: Impact of Whole Brain® and action research

The curriculum fostered learner growth across all four Whole Brain® quadrants. Analytical and practical thinking were developed through coding challenges and prototyping; relational and experimental thinking emerged in team-based projects and design iterations. The use of action research enabled real-time responsiveness to challenges, allowing for meaningful adaptation and growth through reflection.

Theme 3: Curriculum responsiveness and skill development

Learners demonstrated significant improvement in coding literacy, problem-solving, communication and creativity. Observation and peer feedback sessions confirmed higher levels of engagement and self-confidence. By grounding the curriculum in backward design, each learning experience was structured around specific outcomes—which improved assessment clarity and learner accountability.

Theme 4: Reflection and iteration strengthened learning

Reflection periods allowed learners to refine their work and actively participate in the learning process. Teachers also used these cycles to identify common misconceptions and adjust instruction accordingly. This continuous loop of observation, reflection and revision made the curriculum dynamic and responsive.

Conclusion

The Whole Brain® Grade 4 coding and robotics curriculum exhibits an innovative and transformative educational methodology, rooted in Whole Brain® thinking, action research and backward design principles. This curriculum integrates twenty-first-century competencies—critical thinking, creativity, collaboration and communication—within a structured, yet adaptable framework, equipping learners to thrive in a dynamic, technology-driven environment. The curriculum adapts to the needs of learners and educators through ongoing evaluation and iterative processes, promoting flexibility and resilience.

The curriculum's effectiveness is rooted in its ability to engage learners with varying preferences for modes of thinking, connect educational activities to real-world challenges and develop critical competencies for future learning and problem-solving. The backward design framework guarantees coherence among educational goals, assessments and practical implementation, whereas action research offers a responsive feedback mechanism for ongoing enhancement. The Whole Brain® curriculum adopts a holistic development model that enhances technical competencies in coding and robotics, while also cultivating essential lifelong competencies for a changing educational and professional environment.

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