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The journey to developing a coding and robotics Whole Brain® curriculum for grade 4

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Abstract

The Fourth Industrial Revolution (4IR) ushered in a period of significant change, requiring the development of 21st century skills such as communication, collaboration, critical thinking, and creativity if one is to thrive in a rapidly changing global environment. Educational robotics became a crucial tool for fostering these fundamental skills. In light of this, the South African Department of Basic Education (DBE) took the initiative to implement a curriculum that incorporates coding and robotics. However, as the coding and robotics educator at a private school in Tshwane, the first author recognised a deficiency in the fundamental skills that learners need to meet the curriculum requirements set by the DBE. In this article, we examine the development and execution of a Whole Brain® coding and robotics curriculum for grade 4 learners.

Our curriculum development process consisted of three phases: an extensive needs analysis; establishing the need to employ backward design; and the execution of action research. We evaluated the new curriculum using observations, learner feedback, and assessments of learning opportunities, all of which demonstrated its efficacy in improving coding, robotics, and 21st century competencies.

The results revealed substantial enhancements in learner engagement and proficiency in coding principles, evidenced by learners' improved problem solving and critical thinking competencies. The iterative design and reflective analysis processes facilitated the ongoing improvement of the new curriculum, guaranteeing its continued effectiveness.

In this study, we demonstrate the notable progress in coding and robotics education in grade 4 learners and offer a comprehensive structure for curriculum development and execution. We also provide valuable insights for educators, researchers, and policymakers in our having combined action research principles, backward design, and Whole Brain® thinking.

Keywords: 21st century competencies, action research, backward design, coding and robotics, curriculum development, Whole Brain® thinking

Introduction

The Fourth Industrial Revolution (4IR), as highlighted by Butler-Adam (2018), Schwab (2017), and Sutherland (2020), has initiated a significant period of change characterised by the incorporation of sophisticated digital technologies into the worldwide economy and society. To thrive in this dynamic landscape, learners needed to develop the 21st century competencies of communication, collaboration, critical thinking, and creativity (Reaves, 2019).

The field of educational robotics has been recognised as a powerful instrument for fostering 21st century competencies (Díaz-Boladeras et al., 2023; García-Carrillo et al., 2021; Screpanti et al., 2021). Recognising the importance of preparing learners for the future, the South African Department of Basic Education (DBE) embarked on a curriculum reform initiative to include coding and robotics in the education system as a formal subject (Academy of Science of South Africa, 2021; Veldman et al., 2021).

After evaluating the DBE's proposed coding and robotics curriculum (Department of Basic Education, 2021), we[1] identified significant shortfalls that hindered its implementation at a private school in Pretoria, Gauteng; these included a lack of basic coding and robotics competencies among learners and inadequate infrastructure, tools, and instructional time, all of which made it unfeasible to adopt the curriculum as prescribed by the DBE. Therefore, we focused on the design and development of a Whole Brain® coding and robotics curriculum for grade 4 learners. Drawing on principles of backward design, this new curriculum was carefully crafted to align with the needs and learning preferences of the learners and of the school. We employed an action research process to monitor the effectiveness of the curriculum to ensure that it met the desired learning competencies.

In light of the dynamic landscape of educational technology and the imperative to provide learners with relevant and effective learning experiences, we sought to address the primary research question, "How can researchers 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?" To further explore the prospects of implementing an action research-driven self-monitoring process for curriculum design and development, we addressed the following secondary research questions:

[1] The first author is an educator at the school and the second and third authors are her supervisors.

- 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-based Whole Brain® coding and robotics curriculum entail?
- How could the Whole Brain® approach enhance the quality of the coding and robotics curriculum for grade 4 learners?
- To what extent could the backward design approach contribute to the development of an effective and engaging coding and robotics curriculum for grade 4 learners?

Literature review

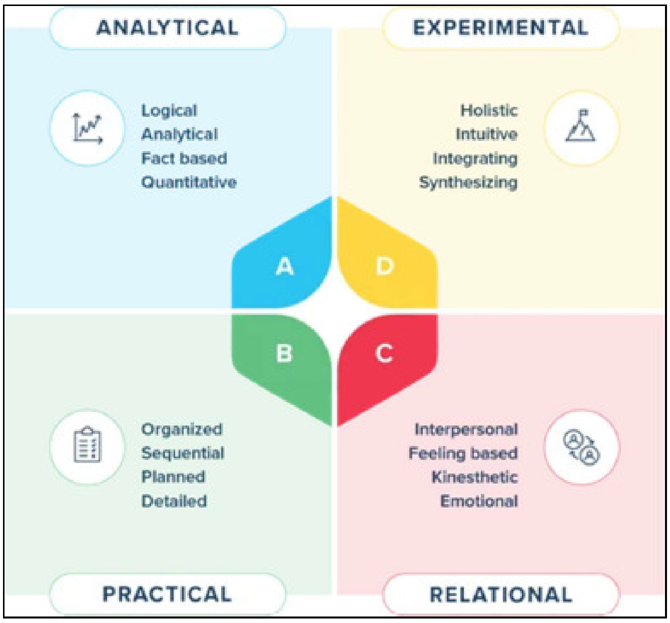
The 4IR and the need for 21st century competencies

To meet the demands of the 4IR and beyond, education systems must embrace innovative approaches that cultivate 21st century competencies, as highlighted by scholars such as Barbazzeni (2021), Du Toit-Brits and Blignaut (2019), Reaves (2019), and Verster et al. (2018). Among these competencies, the 4Cs of the 21st century—critical thinking, creativity, communication, and collaboration—stand out as essential competencies for success (Amri et al., 2019; Budhai & Taddei, 2015; Lathifah et al., 2019). The competencies of critical thinking and creativity are indispensable in a world fraught with complex challenges (Stauffer, 2022; Van Laar et al., 2020). Individuals must be adept at analysing information, evaluating options, and making informed decisions. These competencies are essential for success in both personal and professional life, in their enabling individuals to assess situations, identify solutions, and make decisions that lead to optimal outcomes (Khoiri et al., 2021; Lathifah et al., 2019). In an increasingly interconnected world, effective communication competencies are crucial (Kivunja, 2015; Stauffer, 2019). Individuals must be able to express themselves clearly, listen actively, and understand diverse perspectives. Effective communication is essential for success in the workforce in enabling employees to collaborate effectively, communicate ideas, and build strong relationships (Hobbs & Frost, 2003). Collaboration and teamwork are essential in a rapidly changing and complex world (Stauffer, 2019; Kift et al., 2010). Individuals must be able to work effectively with others to achieve common goals, so require the ability to collaborate, negotiate, and resolve conflicts. In the workplace, these competencies are vital for completing projects and achieving organisational objectives (Alber, 2012; Killen, 2013). Ramey (2016) has emphasised that success in this era of rapid technological advancement hinges on adopting the right ways of thinking and right behaviours.

Whole Brain® thinking: A framework for cognitive diversity

Whole Brain® thinking, developed by Ned Herrmann, is a cognitive process that acknowledges the diverse thinking preferences of individuals, as illustrated in Figure 1 (Herrmann, 1995). This approach categorises thinking into four quadrants—analytical, practical, relational, and experimental—and suggests that individuals have preferences for modes of thinking in each quadrant (Herrmann Global LLC, 2017).

Figure 1
Basic Whole Brain® thinking model (Herrmann Global LLC, 2017)



Analytical thinking (Quadrant A) is linked to the cognitive processes of logical, rational, and systematic thinking (Herrmann, 1999; Herrmann-Nehdi, 2010; Herrmann Global LLC, 2016, 2022). Herrmann (1995) stated that this thinking preference is characterised by critical analysis, problem solving, and meticulous attention to detail. Herrmann-Nehdi (2010) elaborated that it also includes the ability to analyse intricate problems by dividing them into more manageable parts and recognising patterns and connections.

Practical thinking (Quadrant B) is distinguished by a pragmatic and hands-on approach to solving problems. This mode of thinking is focused on achieving outcomes (Herrmann-Nehdi, 2010; Herrmann Global LLC, 2016). Individuals with this thinking preference possess the ability to identify practical solutions to immediate problems and exhibit a keen understanding of how to accomplish tasks with efficiency (Herrmann International, 2018).

Relational thinking (Quadrant C) involves comprehending and appreciating the connections and significance of relationships, whether they are between concepts or individuals. Herrmann-Nehdi (2010) emphasised that individuals who exhibit a preference for this cognitive approach possess qualities such as empathy, intuition, and a heightened awareness of the emotions and viewpoints of others. They demonstrate exceptional proficiency in cooperative environments and possess a remarkable ability to establish strong relationships and cultivate a sense of unity in a team (Herrmann Global LLC, 2016). Herrmann-Nehdi (2010) highlighted that individuals who possess relational thinking competencies are frequently adept at communication and possess the capacity to establish meaningful connections with others on a personal level.

Experimental thinking (Quadrant D) is distinguished by resourceful, inventive, and visionary methods of thinking (Herrmann Global LLC, 2022). Herrmann-Nehdi (2010) noted that individuals who prefer this thinking style are characterised by their curiosity, openmindedness, and willingness to engage in risk-taking. Herrmann-Nehdi (2010) explained that in settings that foster creativity and innovation, experimental thinkers excel and frequently contribute original solutions to intricate problems.

Whole Brain® thinking and 21st century competencies

Herrmann-Nehdi (2010) advocated that Whole Brain® thinking is a valuable addition to 21st century competencies since it is a model that encapsulates various thinking preferences. This model has evolved into a framework for learning and performance and offers insights into how different regions of the brain work together to facilitate cognitive processes (De Boer et al., 2001; Herrmann-Nehdi, 2010). Given the need to maximise individuals' potential in the 4IR, contemporary thought includes Whole Brain® thinking in the list of 21st century competencies. This approach acknowledges and leverages the diverse thinking preferences and learning styles exhibited by individuals, making it a valuable addition to the competencies needed to thrive in the era of rapid technological advancement.

Using coding and robotics to cultivate 21st century competencies and Whole Brain® thinking

The integration of coding and robotics has emerged as a powerful tool with the potential to revolutionise learning in the rapidly changing field of education. Educational robotics fosters an environment that promotes the development of 21st century competencies (Eguchi, 2014; Lathifah et al., 2019) and Whole Brain® thinking.

Coding and robotics enable learners to analyse intricate problems and divide them into smaller, more manageable components. Using this process cultivates analytical and practical thinking and promotes the development of inventive problem-solving competencies (Kayembe & Nel, 2019). In addition, coding and robotics foster experimental thinking and creativity (Kayembe & Nel, 2019; Yang et al., 2020), allowing learners to cultivate inventive problem-solving competencies for real-world problems. Further, coding and robotics enhance collaborative problem solving, verbal communication competencies (Eguchi, 2014; Bers et al., 2019), and relational thinking skills. By engaging in group projects and collaborative problem solving, learners acquire the ability to communicate proficiently and function cohesively as a team. Ultimately, coding and robotics provide a comprehensive learning opportunity that actively involves learners' Whole Brain® thinking. By incorporating these technologies into education, learners are provided with the essential competencies required to thrive in the 21st century. As educators, it is essential for us to adopt and utilise these innovations to establish a captivating and efficient learning environment for all learners. By integrating Whole Brain® thinking into educational practices, educators can create dynamic learning environments that support the development of 21st century skills, which are further enhanced by the integration of educational robotics.

Despite growing recognition of the importance of 21st century competencies and the integration of coding and robotics into education, limited research exists on curriculum models that holistically support cognitive diversity through structured frameworks like Whole

Brain® thinking. Most existing approaches do not explicitly address how varied thinking preferences influence learners' engagement and their development of skills. This gap underscores the need for a tailored, inclusive pedagogical model that bridges cognitive theory and practical learning experiences. The Whole Brain® approach offers a promising framework from which to address this challenge by aligning coding and robotics with diverse thinking preferences, thus fostering deeper, more meaningful learning. To explore the effectiveness of this approach, our study employed an action research methodology that allowed for iterative curriculum development, reflective teaching practice, and responsive adaptation to learner needs.

Methodological framework

For this study, we believe that a well-grounded plan is essential, encompassing paradigms, methodologies, and designs to guide the research process. Our research philosophy, shaped by the works of Crossan (2003) and Kivunja and Kuyini (2017), highlights the significance of guiding beliefs that inform research actions and facilitate comprehension of the nature of reality (ontology) and the process of knowledge generation (epistemology).

We embrace an interpretive ontological perspective, acknowledging the existence of many different realities and asserting that knowledge is constructed through subjective experiences. This methodology entails examining the subjective perceptions of participants through observations, focus group interviews, and semi-structured interviews to comprehend their insights and perspectives.

We utilised socio-constructivism to generate knowledge regarding the social realm, specifically the educational setting. This viewpoint argues that knowledge is acquired and formed through interactions with others and that this includes actively engaging with pertinent literature and learning from one's own experiences.

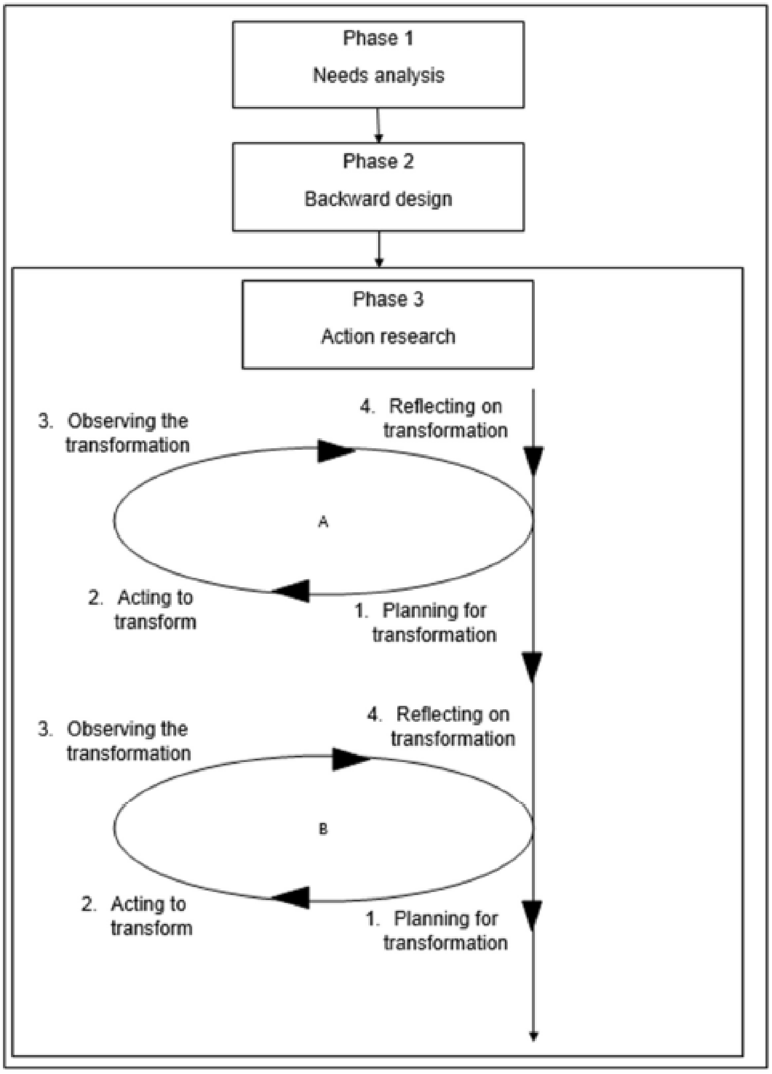
Our research primarily employed qualitative methods, emphasising the analysis of textual data and descriptive information rather than relying on numerical measurements. The objective was to understand situations in their authentic setting and concentrate on comprehending experiences from the viewpoint of the individuals undergoing them.

We employed action research as the design for our research, supplemented by auto-ethnography. This approach entails ongoing surveillance of the action research process throughout its cycles. We employed Whole Brain® thinking as an innovation and professional development strategy during Phase 3 of the curriculum development process.

We used various methods to gather data that provides a comprehensive understanding of the learning experiences in our classroom. Observations were conducted to capture aspects of learning and teaching experiences that are not always evident in interviews. The Herrmann Brain Dominance Instrument (HBDI®) was employed to identify our thinking preferences, supporting the application of Whole Brain® thinking as the principal learning theory. Additionally, we took photographs of learners' creations, such as robots and programming code, to visually represent their real-life experiences. Text analysis involved examining various texts, including lesson plans and reflections to gain insights into the effectiveness of the curriculum. Semi-structured interviews were used to delve deeper into learners' perspectives and experiences. Field notes were taken during observations to record data that may not have been captured by audio recordings. Finally, journaling and reflection were employed as tools to document our thoughts and reflections before, during, and after engaging in learning experiences, providing valuable insights into our teaching practice.

Method

Figure 2
Curriculum development plan



In the course of this study, an action research-driven curriculum design model was developed to guide the creation of the Whole Brain® coding and robotics curriculum for grade 4 learners. This model, illustrated in Figure 2, embodies three phases. These phases include a comprehensive needs analysis, the application of the backward design approach, and the implementation of action research principles. Each phase is intricately connected, contributing to the overarching goal of creating a dynamic and transformative curriculum that meets the diverse needs of learners. Figure 2 further illustrates a spiral-based model of the action research process, where each cycle builds upon the previous one. It begins with Cycle 1, showing the four stages of plan, act, observe, and reflect. The output of the reflection stage feeds into the planning stage of Cycle 2, which then repeats the process, forming a continuous spiral. This design visually emphasises the non-linear, developmental nature of the research and shows how insights and adjustments compound over time, promoting sustained curriculum transformation and educator growth.

Phase 1 of the curriculum development process involved a comprehensive needs analysis, which analysed the learners' profiles, educator profile, and environmental and learning conditions. According to Kaufman (1977), a needs analysis is a systematic approach to identifying gaps between current conditions and desired objectives or outcomes, focusing on prioritising the resolution of these gaps. As explained by Zohoorian (2015), this investigative process involves a comprehensive analysis of learners' backgrounds, competencies, weaknesses, and cognitive competencies. It also includes examining the educator's profile that encompasses their qualifications, experience, teaching methods, professional development requirements, and adaptability to new teaching approaches and technologies. Additionally, the educational environment, including the physical learning environment, the availability of resources and technology, the level of support from administrators and parents, and any socio-economic factors that may influence the learning process were taken into consideration. Lastly, the desired competencies were also identified to align the curriculum with 21st century learning outcomes.

The needs analysis revealed three critical gaps: learners lacked foundational skills to engage meaningfully with the DBE's coding and robotics curriculum; the educator required targeted professional development to effectively deliver content; and the school faced resource limitations, including insufficient technological infrastructure and reduced instructional time. These findings shaped the research aim to design a context-responsive curriculum that would not only address these practical challenges but also intentionally develop learners' 21st century competencies.

Phase 2 employed the backward design approach, aligning desired competencies, such as the 21st century competencies and the Whole Brain® thinking competencies, with suitable assessment and learning opportunities to enhance effective competency development (Emory, 2014; Knowledge Base, 2021). This curriculum design model prioritises a shift away from the conventional term *instructional design* towards a modern concept called *means of facilitating learning*. This change in terminology indicates a wider and more comprehensive approach to the development of curriculum. It includes not only the creation of instructional materials but also the deliberate design of learning objectives, assessment possibilities, and the learning setting. This alignment guarantees that the teaching and learning experiences are more efficient, ultimately resulting in enhanced learning outcomes for learners.

Using this design framework, we crafted and implemented a competency-based curriculum in a grade 4 classroom, grounded in Whole Brain® thinking and supported by action research cycles. Each learning opportunity was framed by clearly defined competencies, linked to practical assessments, and tailored to meet diverse thinking preferences. Implementation occurred weekly over three terms, with cycles progressing through iterative phases of planning, action, observation, and reflection.

This approach proved effective in enhancing learner engagement, problem-solving skills, collaboration, and creativity. Learners demonstrated increased confidence in using the LEGO® Spike Prime™ robotics kits and showed progress in mastering block-based coding and engineering principles. The researchers noted improved differentiation and inclusion given the Whole Brain® model, which supported analytical, practical, relational, and experimental thinking.

Ongoing reflections and data analysis led to several refinements. For instance, learning tasks were adjusted to better match learners' initial skill levels, particularly for those lacking foundational knowledge in mechanics or coding. Collaborative grouping strategies were revised to enhance peer support and engagement. Additionally, more formative assessment checkpoints were designed to monitor competency development in real-time. These changes ensured that the curriculum remained adaptive and responsive to both learner needs and environmental constraints.

Phase 3 involved the application of action research, characterised by a cyclic process that facilitated continuous improvement of the curriculum based on ongoing observations and reflections (Du Toit, 2012; McNiff, 2016). Each cycle encompasses four key steps: planning for transformation or innovation; implementing the innovation; observing the outcomes; and reflecting on the implementation process, with each cycle informing the next cycle. While the term *educational change* is commonly used in the literature (Fullan, 2016; Hargreaves et al., 2011), we prefer the term *educational transformation* to reflect our aim of fundamentally transforming our teaching practice and considering ourselves transformational practitioners. This approach enables the educator to continually improve and adapt the curriculum to meet the changing needs of learners. During these stages, our objectives were to not only create a curriculum but also revolutionise our approach as educators, adhering to the principles of inclusive and participatory learning.

Each cycle's reflective component was pivotal. By analysing learner responses, assessing competency development, and noting challenges or successes, we could adapt materials, instructional methods, or group dynamics for subsequent cycles. This process allowed the curriculum to remain agile, responding in real time to learner needs, contextual limitations, and pedagogical insights.

Living landscape

The classroom is equipped with ten large desks, arranged in a way that allows for collaborative group work. Sixteen learners were divided into eight groups of two learners each, ensuring that pairs could work closely together, providing mutual support, and enhancing learning through discussion and shared problem solving. Pairing learners strategically (e.g., a stronger learner with a weaker one) can help in peer teaching during which learners help each other understand concepts. Each group had access to one LEGO® Spike Prime™ Robotics set, consisting of building elements, motors, sensors, and a programmable hub, as well as one tablet for programming the robots.

The study involved sixteen participants in two classes, with varying linguistic backgrounds, such as English, Mandarin, isiZulu, Sesotho, and Tswana home language speakers. All were grade 4 learners, aged 9 to 10, with a balanced gender distribution. The demographic analysis provides a foundation for further study analysis.

Discussion and results of a Whole Brain® grade 4 coding and robotics curriculum

Action research phases

The action research process for developing the Whole Brain® coding and robotics curriculum involved three critical phases as illustrated in Figure 2.

Phase 1: Needs analysis: School needs

The initiative to introduce a coding and robotics curriculum at an independent English medium school in Pretoria, South Africa, was driven by the school's objective to offer a comprehensive educational programme that included academic, sports, and cultural activities. The school's administration identified coding and robotics as a critical area for academic enhancement. In response to the DBE's proposed curriculum, which did not align well with the learners' current competencies, the school decided to develop a custom curriculum tailored to the needs and competencies of its learners.

Learner profile

Grade 4 learners, aged 9 to 10, were invited to participate in the study. The diverse cultural backgrounds of the learners included being Afrikaans, English, Korean, isiZulu, Sesotho, Tswana and being of Chinese descent. Initially, the participants were divided into groups of four in Term 1, but this was adjusted to pairs in Term 2 after the school acquired additional LEGO® Spike Prime™ sets. This adjustment aimed to enhance the hands-on learning experience and facilitate better engagement.

Situation analysis

Classrooms featured durable furniture, motivational posters, and effective lighting, with separate chalkboards for quotes and reminders. The robotics classroom was furnished with dual desks, a whiteboard, and a projector, along with an increasing number of LEGO® Spike Prime™ sets. The storage room was meticulously organised with yellow bins for resources, each item numbered for easy allocation. Initially without tablets, the school later introduced 11 Samsung Galaxy Tab A7 Lite tablets in Term 1, thus enhancing learning with their portability and performance.

Phase 2: Backward design

The curriculum development process began by our identifying the core competencies that learners needed to acquire. These competencies were carefully crafted to include not only technical skills in coding and robotics but also broader 21st century competencies and Whole Brain® thinking competencies.

To ensure that these competencies were effectively developed, a variety of learning opportunities were developed. These learning opportunities included building basic structures with LEGO® blocks and the understanding of basic mechanics, problem definition, and the utilisation of the colour sensor for story creation, building, and evaluating prototypes, defining and customising new objects, basic coding proficiency, and basic engineering and design proficiency. This was assessed through observation, participative discussion, and peer assessments. Both formative and summative assessments were used to track learners' progress and understanding.

The teaching experiences were designed to be engaging and interactive, with a strong emphasis on hands-on learning. Learners were guided through practical tasks related to problem-solving and coding, allowing them to apply theoretical concepts in a real-world context. Additionally, reflective and collaborative discussions were encouraged, enabling learners to share their thoughts and ideas with their peers and teachers.

Phase 3: Action research cycles

The first action research cycle introduced LEGO® blocks and basic mechanics to learners, involving practical tasks like switching a hub on and off, creating pictures on the hub using the lights, and programming motors to move. The hands-on activities promoted experiential learning, analytical thinking, and collaborative problem-solving, aligning with the HBDI® framework. Challenges included technology access and group collaboration issues, emphasising the need for adaptability and cohesive teamwork. The cycle emphasised critical thinking and innovation in robotics.

Cycle 2 focused on problem solving with colour sensors and storytelling, with learners divided into groups of four for tasks requiring analytical thinking, practical construction, and programming. They demonstrated proficiency in using the colour sensor and storytelling elements, showcasing innovative thinking and relational competencies. Despite challenges such as equipment availability, learners skilfully crafted clear problem statements and used the colour sensor effectively.

Cycle 3 emphasised prototyping and testing grabber designs. Learners were divided into groups of four. These tasks required analytical thinking, practical construction, and programming. Learners demonstrated proficiency in understanding prototypes, their importance, and the benefits of many prototypes. Despite challenges, such as learners leaving early for sport, the remaining learners engaged effectively in prototyping activities.

During Cycle 4 and 5, learners evaluated grabber efficiency and product reviews, choosing the best prototype and justifying their choice. These tasks required analytical thinking, and practical construction. Despite challenges such as equipment availability and time constraints, learners carefully assessed each prototype and justified their choice based on predefined criteria.

In Cycle 6, the focus shifted to improving design and functionality of objects through analytical, practical, and relational thinking. Learners demonstrated comprehension of arguments, constructed persuasive arguments, and tailored the use of new things. Challenges included absenteeism, technical hurdles, and emotional issues. However, learners showcased their ability to assimilate innovative concepts and viewpoints, demonstrating receptiveness to fresh educational encounters and proficiency in innovative troubleshooting.

Cycle 7 focused on enhancing learners' proficiency in using the LEGO® Spike Prime™ application, since the tablets for coding had arrived. This cycle emphasised experiential learning and collaborative learning among pairs. Observations revealed varying levels of proficiency, with learners demonstrating practical, analytical, relational, and experimental thinking preferences. Challenges included learners' reluctance to engage in independent exploration and unexpected technical limitations, thus emphasising the need for structured guidance and contingency planning.

Throughout Cycle 8, the focus was on enhancing learners' coding competencies through the exploration of advanced coding constructs using the LEGO® Spike Prime™ application and set. The learners were assigned the task of converting a robot called the Hopper, which utilises arm-like structures for movement, into a fully operational driving robot. After the conversion, learners had to programme the robot to move in complex patterns. Observations during the transformation phase revealed varying levels of success, with hands-on learners demonstrating confidence and analytical thinkers facing challenges.

Cycle 9 focused on enhancing organisational competencies for LEGO® Spike Prime™ sets. Learners had to arrange and store the sets with a focus on organising and packing them efficiently. Observations during the transformation phase showed a noticeable progression in learners' ability to manage and coordinate the sets, reflecting improved communication and a deeper understanding of organisational competencies.

Cycle 10 aimed to advance learners' geometric coding competencies using loops with the LEGO® Spike Prime™ application and sets. The learning opportunity focused on creating a programming code for the Hopper to navigate through a maze that required analytical thinking, logical reasoning, and collaboration. Overall, this challenge provided learners with a rich learning experience in integrating analytical thinking, experimental thinking, logical reasoning, and collaboration, developing essential coding competencies, problem-solving competencies, and teamwork dynamics for real-world applications in robotics and technology.

Cycle 11 of the action research focused on enhancing learners' coding skills through design and iterative prototyping. Learners designed and programmed miniature cars, thus emphasising creativity and problem-solving. They brainstormed designs, selected prototypes, and created physical models. Coding the cars involved logical thinking, testing, and troubleshooting. The cycle promoted collaboration and innovation but posed challenges for less experienced learners. Structured feedback and support were key in overcoming these challenges and fostering creativity, innovation, and teamwork.

During Cycle 12 of the action research the focus was on enhancing learners' planning and design skills. They were tasked with creating either a miniature golf course or a simulated pet using recyclable materials and incorporating the LEGO® Spike Prime™ sets. The project aimed to develop learners' competencies in planning, designing, and sustainable practices. Learners analysed and evaluated design concepts, planned and designed their projects, and applied effective planning and sustainable design principles. Collaboration was key since learners worked together to refine their designs and present their final concepts. The cycle fostered creativity, critical thinking, and problem-solving skills thus preparing learners for future design challenges.

In Cycle 13 the focus shifted to integrating coding and robotics into projects. Learners constructed their miniature golf courses or pets using recyclable materials and LEGO® Spike Prime™ sets and then created programming codes to control the movement and interactions of their projects. This phase aimed to cater to various thinking preferences and promote environmental sustainability. Learners demonstrated analytical, practical, creative, and collaborative thinking throughout the process. Challenges included varying levels of coding proficiency among learners, requiring individualised support and fostering an inclusive coding environment. Overall, the cycle aimed to develop coding competencies while nurturing a mindset of creativity and innovation among learners.

In Cycle 14 of the action research, the focus was on learners' testing, refinement, and presentation skills. The cycle aimed to enhance learners' competencies to test their projects, iteratively improve them, and effectively present their work to their peers. Testing and iterative improvement involved learners actively testing their miniature golf courses or pets, identifying issues, and incorporating feedback to refine their designs. This process encouraged critical thinking and problem-solving skills, particularly favoured by those who prefer analytical thinking. Presentations provided learners with an opportunity to showcase their work and enhance their communication and presentation competencies, valued by those who prefer a structured approach. Reflection on the testing and iteration process helped learners to develop a deeper understanding of design and coding principles, especially beneficial for those who value holistic thinking. Overall, the cycle effectively fostered collaboration, critical thinking, and problem-solving competencies, while also sharpening vital competencies in communication and presentation.

Findings of a Whole Brain® grade 4 coding and robotics curriculum

The implementation of the action research-based Whole Brain® coding and robotics curriculum at this school marks a significant milestone in innovative educational practices. For six months, this curriculum was carefully designed and implemented for a cohort of grade 4 learners and aimed to create a holistic learning experience that engages learners cognitively, emotionally, and kinaesthetically.

Identification of pre-existing conditions

One of the initial steps in the implementation process was identifying the pre-existing conditions necessary for successful curriculum implementation. This included ensuring that the school had the necessary infrastructure and resources, such as the classroom equipped with LEGO® Spike Prime™ sets, tables on which to build the robotic sets, Wi-Fi, and up-to-date tablets. Inclusive education practices were also crucial to ensure that all learners, regardless of background or ability, could participate fully in the curriculum.

Development of an action research Whole Brain® curriculum

The action research-based Whole Brain® coding and robotics curriculum was developed based on the principles of action research, backward design, and Whole Brain® thinking. It aimed to engage learners in constructing structures, utilising sensors, and participating in practical activities to develop not only coding and robotics competencies, but 21st century competencies and Whole Brain® thinking competencies. The curriculum incorporated diverse teaching opportunities, such as constructivism, group work, and experiential learning, to cater to learners' diverse learning preferences. It also emphasised the importance of collaboration, hands-on learning, and the creation of prototypes to enhance learning opportunities. This approach was instrumental in providing learners with a comprehensive learning experience that not only focused on technical concepts but also emphasised the application of knowledge in real-world scenarios.

Evaluation of effectiveness

The effectiveness of the curriculum was evaluated through observation, feedback from learners, and assessment of learning competencies. Observation was used to assess learners' problem-solving competencies, understanding of coding and robotics concepts, and progress over time. Feedback from learners, obtained through reflections and peer evaluations, provided insights into their learning experience and helped identify areas for improvement. Assessment of learning outcomes focused on measuring the development of technical, problem-solving, cognitive, and interpersonal competencies in learners.

Overall, the implementation of the action research-based Whole Brain® coding and robotics curriculum was successful in engaging learners and enhancing their coding and robotics competencies. The curriculum provided learners with a comprehensive learning experience that integrated theoretical knowledge with practical application, resulting in the development of 21st century competencies such as critical thinking, creativity, collaboration, and communication and Whole Brain® thinking competencies. It highlighted the importance of the backward design approach in creating effective and engaging coding and robotics curricula for grade 4 learners.

Limitations

This study has several limitations that affect its generalisability and scope. Focusing exclusively on grade 4 learners and a specific coding and robotics curriculum, the findings may not be transferable to other educational settings or grade levels. The restricted sample size limits the comprehensiveness of the insights, and a larger sample would provide a more thorough understanding of the curriculum's challenges and opportunities.

Subjectivity given our dual role as educators and researchers could have introduced bias, despite efforts to ensure data reliability through reflective practices. Time constraints limited the opportunity for detailed interviews or observations, and resource limitations, such as limited access to tablets and robotics sets, affected curriculum implementation and learner experiences in the first action research cycle.

External factors, including unexpected events that included learners leaving early for sport and learners being absent, impacted the study results. Although attempts were made to mitigate these factors, their influence cannot be completely disregarded.

Contributions of the study

This study significantly advances the field of education by offering insights into creating and executing coding and robotics curricula for grade 4 learners. It enhances existing literature by incorporating action research principles and Whole Brain® thinking into curriculum development, providing a detailed framework to address challenges and leverage opportunities in developing tailored programs for diverse learner needs.

The study highlighted challenges and opportunities in curriculum development and implementation, thus providing insights for educators and developers. It emphasised addressing technology accessibility, group dynamics, and time management, while promoting self-directed exploration and improving facilitation methods. Through observations, reflections, and interviews, the study shows how this curriculum enhances learners' creativity, collaboration, and problem-solving skills, crucial for future technological environments. By grounding the curriculum in established educational theories and frameworks, the study boosts its credibility and offers a theoretical framework applicable in various educational settings. The study showcases an innovative approach to curriculum development using action research, ensuring that the curriculum is continually improved based on feedback and observations.

Overall, this study provides a comprehensive framework for curriculum development and implementation in coding and robotics education, laying a valuable groundwork for future research and benefiting educators, researchers, and policymakers in STEM education.

Conclusion

This study represents a significant advancement in the field of education, particularly in the realm of coding and robotics curriculum development for grade 4 learners. By incorporating action research principles and Whole Brain® thinking, the study has provided a detailed framework that addresses the challenges and opportunities inherent in creating and implementing tailored programs for diverse learner needs.

The study provides valuable insights for educators and curriculum developers by focusing on identifying pre-existing conditions for implementing an action research-based Whole Brain® coding and robotics curriculum. It also enhances the coding and robotics curriculum for grade 4 learners through the Whole Brain® approach. Additionally, the study highlights the contribution of the backward design approach to creating an effective and engaging coding and robotics curriculum for grade 4 learners. The curriculum developed and implemented in this study not only enhances learners' coding and robotics competencies but also fosters critical 21st century competencies such as creativity, collaboration, communication, and critical thinking.

The study's theoretical foundation in established educational theories and frameworks, coupled with its methodological innovation in using action research, ensures the credibility and validity of this curriculum. This study not only provides a practical framework for educators and curriculum developers but also lays a valuable groundwork for future research and curriculum development in coding and robotics education.

In essence, this study's contributions extend beyond its immediate context, benefiting educators, researchers, and policymakers in STEM education by providing a comprehensive framework for curriculum development and implementation. As technology continues to play a crucial role in education, the insights and framework provided by this study will be instrumental in preparing learners for the challenges and opportunities of a technology-driven world.

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