

Exploring Basic Programming Education in Primary Schools as a Foundation for Introducing Artificial Intelligence, Augmented Reality and Virtual Reality Technologies

Beauty Mugoniwa^{1*}, Mampilo Phahlane^{2*}, Charles Mbohwa^{3*}

* Computer Science Engineering and Technology, University of South Africa, Florida Campus, South Africa.
mugonb@unisa.ac.za¹ ORCID: 0009-0003-5080-6926, phahlmm@unisa.ac.za² ORCID: 0000-0002-0313-8094,
mbohwc@unisa.ac.za³ ORCID : 0000-0002-8268-5984

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ABSTRACT

As emerging technologies such as artificial intelligence (AI), augmented reality (AR), virtual reality (VR) become increasingly integrated into educational context, primary school children need to be equipped with basic programming principles so that they can then be engaged in more advanced applications. The study guided by Pedagogical Content Knowledge (PCK) and a conceptual framework, conducted an SLR to investigate the basic programming courses designed for primary school children. The aim of the study is to evaluate how these basic principles support cognitive development and technological readiness in relation to AI/AR/VR education and its applications. Article search was conducted in Scopus, ERIC, IEEE Xplore, ACM digital library for peer reviewed articles and Google Scholar for more supporting literature published between 2018 to 2025. The combination of SPAR-4-SLR and PRISMA methods was employed to ensure rigor in article selection, screening and compilation of findings. In addition, thematic synthesis was used to analyse the findings. The study analysed the gap between programming and demands of 4IR technologies and applications. We uncovered that although there is limited literature on programming in primary schools in South Africa (S.A), the few studies that we came across are coming up with many ways of introducing programming to students, plugged and unplugged. These are being administered as game-based, teacher instruction-based, collaboration and /or individual teaching methods. And this is gradually adding to the computational thinking and basic programming skills need by students to be able to tackle the development of AI/AR/VR tools and applications.



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I. INTRODUCTION

South Africa's primary and secondary education system is facing substantial challenges, particularly in subjects like mathematics, science and even basic literacy like reading. This is evidenced by the findings from Progress Reading Literacy Study (PIRLS) conducted in 2021 which highlighted that at least 80% of Grade 4 pupils in South African schools could not read [1]. This is particularly concerning given that AI, AR and VR are technologies that are underpinned by disciplinary knowledge in fields such as computer science, mathematics and engineering. For students to engage with and

contribute to these 4IR technologies, a strong foundation in these subjects is mandatory before considering introducing them to basic programming principles. Additionally, it is equally essential to teach pupils early about the technical and basic principles behind AI, AR and VR, these are data structures, data algorithms, basic coding and programming [2], [3], [4], [5].

Despite the above concerns, AI, AR and VR technologies are increasingly integrated into primary and secondary education systems among other sectors such as healthcare, finance and automotive. This is being done to foster creativity, collaboration, engagement and problem-solving

skills among primary and secondary school children [2], [6], [7]. Currently there has been a global push to introduce basic programming in early childhood education to enhance computational and logical thinking as well as creativity together with cognitive skills that enable understanding and interacting with the 4IR technological systems. In addition, this supports students in their navigation of a technology driven world [4], [8], [9], [10].

This study investigates how basic principles of programming are embedded in primary school curricular before students are exposed to interacting with AI, AR and VR and their applications. It is imperative for developing countries like S.A to engage in “catch them young” principle, for the acceleration of development thereby achieving the sustainable development goals[3]. Extant literature focuses on implementation and development of AI, AR and VR in Secondary and Tertiary education [1], [7], [8], [11], [12], [13], [14], [15], [16], [17] and application of these technologies and in primary education it is mostly the application[18], while fewer schools with programming do not have clear curriculum guidelines on basic programming principles like data structures [19]. The SLR investigates the extent to which the basic programming skills align with the demands of contemporary technological tools. It aims to present a review that provides valuable insights about the research trends for the teaching activities in programming subjects in primary school grades in S.A. Extant literature reviews are limited in programming, AI, AR and VR in primary schools in S.A, where most of SLR are targeting higher and tertiary education[20], [21], [22], so in this study we focus on filling this gap.

In this study we investigate the application of basic programming in preparation for AI/AR/VR developments and applications by answering these three Research questions (RQ)

- What basic programming/ coding principles and concepts taught in primary schools in S.A?
- Why should basic programming/coding principles and concepts be taught?
- What teaching methods and tools have been to introduce basic programming in preparation for AI, AR and VR learning?
- What challenges and enabling factors influence the success implementing of basic programming in South African primary schools?

The rest of the paper is structured as follows, theoretical development; tools and methods; presentation of findings; discussion of findings; recommendations and future directions and conclusions.

II. THEORETICAL DEVELOPMENT

AI can be defined as an interdisciplinary science, that is used to create intelligent machines that imitate and simulate human cognitive processes [2], [6]. With VR, AR, and AI traditional educational environments are replaced by exciting, virtual, immersive, collaborative, and personalised learning

experiences. VR is a software that uses multisensory inputs, such as images, sound, computer graphics to recreate and reproduce digital life situations that allow someone to experience a scenario that can be referred to as imaginary world, that is different from the environment the person is currently in [23]. VR compliments an environment where all explorations, simulations are replacing laboratory experiments, which are also a scarce resource in most schools. The facility is extended to science subjects for experimental purposes such as rigorous gymnastic exercises, surgical operations and gaming facilities like wrestling, posing a risk-free experience, with less expensive environment, no need for physical well-furnished theatre and life compromised environment [24], [25], [26], [27].

AR uses technological components (such as tablets, mobile devices, AR glasses), information and perceptual components to superimpose digital content in form of sound, visuals and other virtual elements onto real world environments, course content that may be difficult to understand theoretically can be simulated and brought to life enabling an interactive and engaging experience[23]. In AR, information that is challenging to present and illustrate, such as content in life sciences and engineering disciplines can be represented through 3D models [25], [26], [27].

AI-powered tools provide students and staff with personalised content based on the parameters given in the interactive platform. It is a powerful and interactive search engine that can analyse vast amounts of information and retrieve customised information according to the specification of the user. AI can be applied in many aspects of education by learners and teachers since it allows for personalised learning, intelligent tutoring systems, facilitated assessments, grading and predictive analysis [26], [28], [29], [30].

AI/AR/VR is compelling when it comes to teaching and learning purposes and is expected to add value to learning experience, engagement, overcome state of art limitations in pedagogical settings, however there are currently few educational applications to be used in classroom settings [1], [31], [32], [33]. Having discussed the essentials of AI, AR and VR, we seek to clarify that these applications are developed, and the development process needs to start at tender ages, cultivating programming talent which is a vital skill so that as the technology advances, seasoned programmers will be available to improve and update the systems to compete with the demands of age of intelligence[34], [35]. The basic principles of coding and the use of programming is deemed as a vehicle to development of computational thinking in primary schools, additionally it aids with the ability to think abstractly and logically [19], [36]. Therefore, this calls for educators and curriculum developers to actively engage computational essentials in curriculum development to enhance computational as well as logical thinking[19].

In the same vein, we chose the reformulation of Pedagogical Content Knowledge (PCK) theory by Grossman because of the questions that came out of her study, “*why teach a certain subject? what should be taught? what are the*

learning difficulties? and how to teach?”[37]. These questions emphasise how teachers need to translate knowledge into primary-appropriate programming curricular, and lessons as a result. The questions encourage teachers to simplify and adapt advanced concepts by adopting the multiple knowledge domains namely content knowledge (CK) where questions *what should be taught?* is addressed as the teacher will be seeking what contents are available that can be used to blend the programming concepts in the curricula based on teachers knowledge [38], [39], [40]. General Pedagogical Knowledge (GPK), where questions like *what are the learning difficulties? and how to teach?* are addressed as the teachers will be using the effective teaching methods that are used and have proved to work when teaching difficult concepts[38], [40]. Pedagogical content knowledge where questions like *why teach a certain subject? and how to teach?* are addressed by the integration of technology related content and for the integration of technology related content [37], [40], [41].

In AI/AR/VR development these questions help the study in mapping the way we select literature for SLR and explore the basic programming education in primary schools’ situation. The *why teach a certain subject?* part of the PCK questions was answered in the introduction above where emphasis was put on developing critical thinking, problem solving and logical thinking skills[41], [42], [43]. Basic programming skills helps the students to diagnose a problem, find a solution to the problem by critically thinking, designing, and implementing the solution using the syntax, grammar, and logical way of communicating with the computer[37]. *What should be taught?* question requires us to understand the basic concepts of programming suitable for primary school level and what they contribute to the concepts in the development of AI/AR/VR.

Since the core of programming is about problem solving and creating solutions, there are two kinds of knowledge that can be deduced from programming namely program generation and program comprehension, the later entails the students to identify the problem, generates the solution in a well written code[44]. Program comprehension requires the student to demonstrate how the code works, explaining the steps, the forms and processes that are involved, even to the extent of justifying why a certain program was developed [37], [45]. *What are the learning difficulties?* question seek to clarify the common problems that are faced by students while learning programming, these may range from background of children being taught, the resources at school, and subjects that are prerequisite for students to comprehend basic programming principles without difficulties. Programming is regarded as a difficult area, therefore teachers need to implement the GPK strategies so that students will not fail even before they attempt, as many would just regard the subject as difficulty without even willing to attempt[37], [46], [47], [48]. *How to teach?* question requires to seek the best approaches that can be used to introduce students to programming education and demystifying the fact that it is a

difficult learning area. Inclusion of technologies that makes learning interesting and easier is another way primary school teachers can hook students’ motivation effectively [37], [41].

A. Conceptual framework

Basic programming education can be conceptualised as an introductory layer in the development of competencies needed for interaction with 4IR technologies, such as AI, AV and VR. While extant literature has explored emerging technologies and programming education independently, this study adopts an integrative perspective where programming principles are positioned as technical and cognitive precursors to advanced technological interaction [1], [14], [19].

Computational thinking being at the centre of this relationship, have the varieties like abstraction, decomposition, algorithmic reasoning and pattern recognition. These cognitive processes are broadly recognised as core results of programming education and are essential for understanding and interacting with AI-driven systems, AR environments and VR simulating [8], [10]. Technologies such as algorithmic reasoning enables learners to conceptualise how AI systems process input data to generate outputs, while abstraction allows learners to interpret complex virtual environments by focusing on relevant features and relationships [28], [30].

The progression of programming principles found in primary education reflects a structured development of these competencies. If young learners are exposed to sequencing and simple algorithms, they will be taught to master ordered logic and procedural thinking which form the basis for grasping system processes [51], [59]. As learners advance, their development of decision-based reasoning can be supported by introduction of loops and conditionals, and these are critical in modelling intelligent systems and interactive applications [19], [54]. As the y proceed within their education, concepts such as debugging, modular design and variables faster reflective thinking and system optimisation, which are essential for the development and refinement of AI, AR and VR applications [53], [56].

This progression demonstrates that programming education facilitates the development of higher order cognitive abilities that underpin technological fluency, rather than being a mere technical skill acquisition. In line with the PCK framework, the conceptual framework reflects the alignment between what is being taught (foundational concepts in programming), how it is taught (instructive strategies) and why it is taught (development of problem solving and computational skills). In addition, the integration of programming education with AI, AR and VR is backed up by literature, postulating that these technologies on core principles like algorithmic logic, system interaction and data processing [24], [26]. As such, when learners develop strong foundations in programming, they become better positioned to engage with, adapt to and contribute to the development of these technologies.

However, the relationship between 4IR readiness and programming education is not that automatic. Therefore, it should be mediated by contextual factors such as teacher preparedness, curriculum design and resource availability. Studies with S.A context highlight challenges such as inadequate training, limited infrastructure and disparities between under-resourced and well-resourced schools and this affect how programming concepts are delivered and understood [1], [43], [61], [62]. These limitations may affect the level at which computational thinking skills are developed, thereby impacting learners' readiness for advanced technological engagement.

III. METHODS

A. Research Design and Review Approach

This study adopts an SLR design approach to investigate the role of BPE in primary schools as fundamental principles for engagement with AI, AR, VR. The study combines PRISMA and SPAR-4-SLR to guide the review. These two frameworks when integrated ensures both procedural and methodological rigor. PRISMA was used as a transparent flow of article identification, screening and reporting protocol, enabling a transparent flow of article identification, screening, eligibility assessment and inclusion. While SPAR-4-SLR was employed to guide the conceptual and analytical stage in the review process, in addition, SPAR-4-SLR was used for the formulation of research questions definition of search domain, categorising the studies and synthesis of findings.

B. Research Design and Review Approach

Scopus was used as the main database because of its content coverage, practicality, convenience, trustworthy in addition Scopus was chosen because of its wide coverage in terms of the subject area by including such databases as ERIC, IEEE Xplore, ACM digital library which are known to be repositories for educational articles, the other advantage realised whilst using the search function is that it helps by suggesting the parameters one can add to refine the search criteria. The search was conducted for the period from 2018 to 2025. The selected period of 2018 to 2025 marks the rise of rapid growth of coding in young generation where international and local studies have shown great interest in computational thinking [50]. In addition, this period captures the preparation, the initiation of active piloting and drafting formal coding and robotics curricula in S.A. While all efforts were done to find to plenty journal articles on the basic programming education in primary schools in S.A, few related articles were obtained. This may be because the curriculum was introduced only in 2021, and full implementation was expected in 2023 academic year [43], [51]. Although it is said to be fully implemented in 2023, there are still challenges being faced in schools that hinders the full swing of the program, therefore instead of studying what is being done in teaching and learning activities, most studies

are looking at what should be done so that the program can operate smoothly [50], [52].

The search query was addressed as TITTLE-ABS-KEY where ("data structures" OR "basic programming" OR "basic coding" OR "artificial intelligence" OR "augmented reality" OR "virtual reality" OR "primary School" AND "S.A").

C. Inclusion and exclusion criteria

The selection of studies to be reviewed was guided by a clearly defined inclusion and exclusion criteria to ensure consistency and relevance. The inclusion and exclusion criteria presented in table 1 were applied systematically during the screening process to ensure that final dataset aligned with the research aim.

TABLE I
INCLUSION AND EXCLUSION CRITERIA

Inclusion criteria	Exclusion criteria
Studies published between 2018-2025	Studies not in English
Focus on primary schools	Focus on secondary schools/ tertiary
Basic programming/coding education	Other educational issues with no programming/ coding.
Adress AI/AR /VR	Implementation of AI/AR/VR without coding /programming elements
Peer reviewed articles, official curriculum documents, government reports	Blogs, opinion papers and other non-academic articles

D. Screening process

For identifying and screening the articles we were guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) for systematic literature review (SLR) shown in figure 1 below; for a rigorous and transparently conducting the literature review we anchored our SLR with the Scientific Procedures and Rationales for Systematic Literature reviews (SPA-4-SLR) presented in table 2 below. For screening purposes, we included only articles on primary school education in S.A, although from our index search, we yielded 246 entries of which 201 were excluded by title or focus, 6 were unavailable and we remained with 39.

From the PRISMA flow chart we initially focused on Scopus articles in our search for literature review but because the literature in Scopus is still very few, we ended up adding other articles from google scholar, government reports and official policy statements. Articles from grey literature captures current events, reduces publication bias especially articles like reports and they are habitants of practical information especially from governments policies and other institutional reports. The focus of the study is to investigate the basic programming or coding initiations in primary schools, this can be informed by the curriculum policies

written about that, governmental initiatives that captures training rollouts on the subject at hand and other articles that have captured details on what is being done in primary schools to prepared students for AI/AR/VR applications and development.

E. Data extraction and thematic synthesis

Data extract ted from the chosen studies included information on principles of programming, tools used, teaching methods, education level and relevance to AI, AR and VR. Thematic synthesis approach was used to conduct analysis, and this enabled the identification of patterns and relationships across studies. The synthesis was done following 3 stages where open coding was applied as the first stage to extract data and key concepts with recurring ideas were identified which are “game-based learning,” robotic tools” “sequencing” and “loops”. The second stage, axial coding enabled the codes to be grouped into broader categories reflecting relationships between technological relevance, concepts and pedagogies. For examples codes related to conditionals, loops and algorithms were grouped under the category of computation thinking foundations.

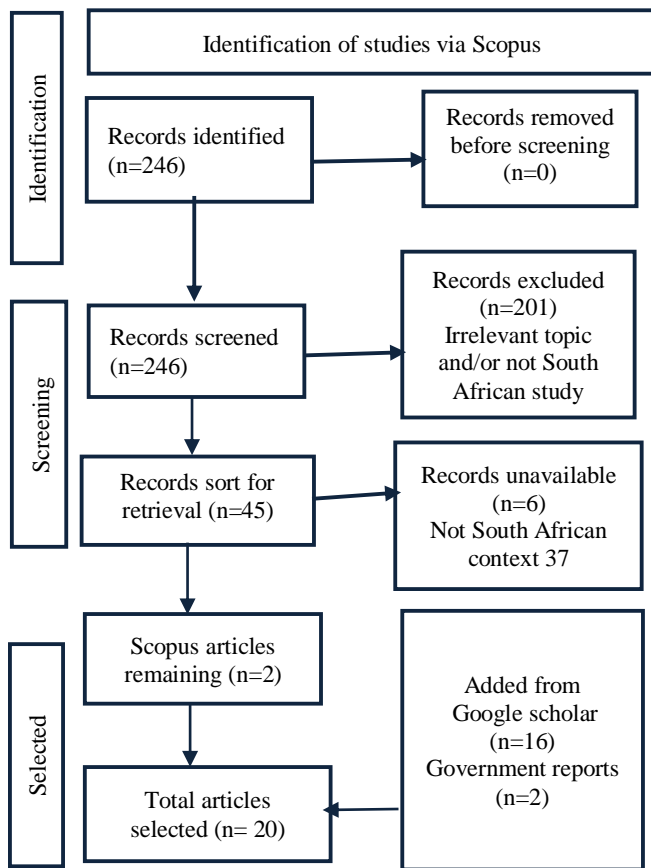


Figure 1: Flow Chart of the PRISMA method

The third stage of selective coding, where overarching themes were developed to structure the findings of the study.

As a result, themes like foundational programming concepts, pedagogical approach and tools and alignment with AI, AV and VR competencies. To enhance validity of the analysis, themes were reviewed iteratively and scrutinised to ensure alignment with the conceptual framework and consistency with the research questions. This process ensured analytical interpretation of patterns and relationships within the literature.

Stage	Sub-stage	Criterion	Rationale	
Assembling	Identification	Domain	Computer science, Programming, Education, Computer engineering	
		Research Questions	What basic programming principles and concepts are taught in primary schools in S.A and why?	
			What teaching methods and tools are being used to introduce basic programming concepts in preparation for AI, AR and VR learning?	
		What challenges and enabling factors influence the successful implementation of basic programming in South African primary schools?		
	Source Type	Academic Articles in English		
	Source Quality	Scopus for wide coverage Google Scholar for adding review content		
	Acquisition	Search mechanism and material acquisition	Scopus and Google Scholar	
		Search period	2018 to 2025	
		Search keywords	Boolean search (OR, AND)	
		Total number of articles returned from the search	246	
Arranging	Organisation	Organisation codes	Theories, programming tools, context, educational level, relevance to AI, AR and VR	
	Purification	Article type included/ excluded	Included English, relevant topic/ excluded context coverage not S.A, not primary school content.	
		Total number of articles retrieved after purification	20	
Assessing	Reporting	Evaluation	Analysis methods	Quantitative analysis and qualitative analysis (frequency and thematic analysis)
		Reporting conversions	Limitations	Tables, graphs, words
		Limitations	Few articles returned from Scopus as the main search criteria and resorting to add articles from Google Scholar	

F. Thematic distribution of the screened data set

The resulting data set of 20 articles was distributed across the identified themes, most of the studies contributed to multiples dimensions of analysis, majority of studies

addressed foundational programming concepts and computational thinking, while a few studies focused on pedagogical approaches such as collaborative and game-based learning. A small and distinct dataset implicitly linked programming education to competencies in AI/AR/VR. The distribution of the datasets highlighted that there are more studies in foundational programming education and at the same time studies explicitly connecting the foundational programming to emerging 4IR technologies are scarce thereby making this review relevant.

IV. RESULT

Table 3 in supplementary file shows the challenges and the enabling factors that affect successful implementation of programming/coding in South African Primary Schools. Where RQ 3: *What challenges and enabling factors influence the successful implementation of basic programming in South African primary schools?* This is being answered by the list of authors indicated in that table. Table 4 in supplementary file shows data extracted from articles that were found to be relevant. Data extracted mainly addresses RQ 1: *What basic programming principles and concepts taught in primary schools in S.A?* This question is addressed in column three in the table 4 in supplementary file with heading Basic programming/coding concepts/principles. In addition, RQ 2: *What teaching methods and tools are being used to introduce basic programming concepts in preparation for AI, AR and VR learning?* is addressed in column four, five and six of the table 4 in supplementary file with the headings Programming tools, Teaching method, Relation to AI/AR/VR respectively.

This study contributes to the body of knowledge by providing a context-specific synthesis of education in principles of programming within S.A primary schools, with a particular focus on its role as a foundation for engagement with AI, AR and VR. While prior systematic review [3], [4], [5] have examined programming education, most of reviews have largely focused on secondary and tertiary institutions, while [19]. have treated computational thinking as a separate entity. Therefore, this analysis reviews the intersection between readiness in 4IR technologies, early programming education and contextual constraints in developing country. The results are presented in three analytical dimensions, namely progression of programming concept, the technological and pedagogical approaches adopted and alignment of elements with competencies required for AI, AR and VR engagement.

A. Core programming concepts

From the analysis done, programming education in S.A primary schools is structured around a set of foundational concepts, including basic data representation, conditionals, loops, algorithms and sequencing. In early grades programming education emphasises sequencing and pattern recognition which support the development of procedural thinking. As learning progress learners are gradually introduced to conditionals and loops, enabling them to engage

in more complex reasoning process involving decision making, logical branching and repetition. At higher levels, concepts such as variables, modular design and debugging begin to emerge, reflecting a transition towards reflective and evaluative thinking.

The conceptual framework guiding this study posits that foundational programming concepts are drivers of computational thinking development. The progression from sequencing to conditionals and modular thinking demonstrates how learners develop cognitive process such as algorithmic thinking, abstraction and decomposition, which form the foundation for subsequent engagement with AI, AR and VR technologies. It demonstrates that programming education does not entail acquiring technical skills only but also cultivating a structured form of reasoning that mirrors the logic underlying 4IR systems and data processing technologies. The review also indicates variability in how the concepts are implemented across schools, within some schools relying on fragmented or informal curricular. The inconsistency suggest that while the conceptual foundation exists, its translation into practice is uneven and this affects the extent to which learners develop coherent computational competencies.

B. Educational approaches, tool selection and contextual adaptation

The study identifies a strong emphasis on learner-centred pedagogical approaches, especially those that leverage games, play and collaboration. These approaches serve as mechanisms for reducing the perceived difficulty of programming. The attention of this study is directed towards interaction between teaching activities like tool selection and socio-economic context. In better resourced schools, programming is facilitated through digital platforms such as scratch and robotics kits, these enable the learners to visualise abstract concepts and engage in interactive problem solving. The resource constrained schools in contrast frequently rely on unplugged methods, for example physical activities, game-based simulations and storytelling.

This study has learned that the choice of tools and methods used is not neutral but is shaped by structural constraints such as policy support, teacher training and infrastructure. The study, rather than viewing the unplugged methods as inferior substitutes, it suggests that they play a critical role in fostering computational thinking in contexts with limited access to technology. Therefore, this study has revealed an important contribution of the study where unplugged programming is taken as a pedagogically valid and contextually adaptive strategy, rather than merely a compensatory measure. From a conceptual perspective, the pedagogical approaches studied and tools selection can be understood as mechanism through which computational thinking is operationalised in practise. Both plugged and unplugged methods aids the development of core cognitive competencies, reinforcing the teamwork's proposition that digital tools are not the only tools for

technological readiness but also the cultivation of underlying reasoning process.

C. Bridging foundational programming and 4IR proficiency

The fundamental contribution of this study lies in its examination of the relationship between basic programming education and the skills required for AI, AR and VR technologies. While most of the reviewed articles do not explicitly address these technologies at primary level, analysis demonstrates that basic programming concepts implicitly support the development of skills that are essential for 4IR engagement. These include abstraction, logical reasoning ability to construct and interpret algorithms and pattern recognition. Such proficiency is fundamental to understanding how AI systems functions, how AR overlays digital information onto physical contexts, and how VR simulations are structured.

However, the findings uncovered a significant conceptual gap. Although programming education lays the foundation for technological, readiness, there is limited explicit demonstration of how these foundational skills connect to AI, AR and VR technologies. This suggest that current curricular may not fully capitalise on the potential of programming education to prepare students for emerging technological landscapes. Therefore, this study managed to highlight the need for a more integrated applications that links foundation programming concepts to real-world applications in an articulate and developmentally- appropriate manner. In addition, the findings support the argument that cognitive skill development in programming is a fundamental precursor to meaningful participation in 4IR technologies. This relationship between basic programming skills and technological competencies directly reflects the conceptual framework in this study, where computational thinking provides the intermediary construct linking early programming education to readiness for AI, AR and VR.

V. DISCUSSION

Synthesis of reviewed articles was organized into predefine categories derived from the theoretical framework that underpins this study. The reformulation of Pedagogical Content Knowledge (PCK) theory by Grossman came up with theoretical questions, “why teach a certain subject? what should be taught? what are the learning difficulties? and how to teach?”[37], that prompted us to develop three research questions that also guided our literature review.

Why teach a certain subject? This question prompted us to develop RQ 1.1: *Why should basic programming/coding principles and concepts be taught?* These questions when answered would be probing for the reasons behind the teaching of basic programming and the tools being used. The goal of the research study is to evaluate how the basic principles in programming, programming tools support cognitive development and technological readiness in relation to AI, AR, and VR education and its applications. So, in response to the why part, we took the basic programming

/coding as the foundation to development programs and if the right foundation is established, with the right tools, students have been equipped to tackle the demands of AI, AR and VR whether it is the development of tools or the application of the tools. In teaching the basic principles and concepts with given programming tools students are equipped with problem-solving/design/thinking skills, as they are faced with problems that need solutions [53], [54], [55], [56], [57].

Programming involves the ability to generate a solution to certain problems, the process of generating is not a one step process, there may be a need to break down the problem at hand into sub problems which may then be solved sequentially, conditionally, in loops or nested constructs [50]. This need a student who is a rigorous thinker, with an appreciation of concepts like functions, variables, debugging, decomposition and generalisation. So, a student who is taught basic programming skills would know when to use which concept and how to synthesise the sub solutions to come up with an integrated solution to the big problem that was there[19], [56], [58], [59].

Students in programming are being taught to talk with the machines in an ambiguous way, that is giving computers instructions on a platform with some interface different from the one they are used to when playing games, using their gadgets in general. When learning the basics of programming students are gaining computational skills and other 21st century skills. Most of the tools used are not intelligent, so all the instructions are coming from the student’s syntax, meaning if the student can give command to unintelligent machines or if they can get a mastery of building up a game with cardboard boxes, it will be much more easier for them to communicate, give instructions to intelligent machines such as those that use AI/AR/VR [1], [19], [51], [55], [56], [59], [60], [61], [62], [63]

What should be taught? This question requires us to investigate what exactly is being taught in South African primary school as programming and coding concepts. The DBE and CAPS of S.Answered this explicitly by indicating what should be taught at each level to the extent of allocating the expected time that should be taken to teach each learning area [59], [64].

In this section our guiding RQ1: *What basic programming principles and concepts taught in primary schools in S.A.?*; seeks to shed light on the basic concepts that students are being taught, bearing in mind that what they are being taught is expected to have been from a curricular designed and agreed upon by school authorities, although research by [19, p. 7]says:

“One participant followed a formal curriculum developed and provided by an independent company.”

“... this participant did not follow a formal curriculum....”

“Two other participants referred to free online curricula that they followed informally.”

Programming basic concepts involve around these three aspects: data, instructions and syntax [37] , while different

teachers may teach many other concepts, but the main goal is to teach programming concepts that are suitable for each student's cognitive level. From the data extracted on programming/ coding concepts, a wide range of concepts were indicated, where some can be grouped according to those three aspects and some concepts support the use of data, instruction and syntax. In *why teach a certain subject?* section we discussed some of the basic concepts that should be taught in coding. Data can be referred to as the "concepts of variables and data types for procedural programming" [37, p. 79] a look at few studies indicated the use of string variables and the use of string(str) data types "Game over", "well done" [19], "Forward", "Backward", and "Wait for Clap"[54], interger variables and the use of integer(int) data types "0 to 180", "0 to (-180)", "0 to 255" and "0 to (-255)" [60]. These were used as they were coding literally and, in some applications, they are used when aligning the coded blocks. Instructions are commands that tells what the computer should do for example AND OR [59] logic instructions used in data processing. Syntax is a group of rules that control data and instructions that is allowed and is not within a programming language, most errors that deter programs from reaching a desired result are syntax errors [53], [59], [60].

What are the learning difficulties? Students who are taught coding face some problems related to the subject being taught and other problems are indirectly linked to the subject. In this section we seek to answer the RQ 3: *What challenges and enabling factors influence the successful implementation of basic programming in South African primary schools?* Programming is stereotyped as a difficult area of study, and most students would be afraid to try it [60] when given the option to choose [51] in addition its associated STEM subjects are also not easy to most students [19], [56], [61], [65]. This reduces confidence in students even during lessons times, they are said to only wait for instructions and do not initiate other learning activities, some are said to pretend to work when they see the instructor and others are afraid to ask questions [60].

The other learning difficult is lack of resources, poor infrastructure and digital divide [1], [54], [55], [56], [57], [58], [60], [61], [62], [63], [66], [67]. South African schools are faced with poor infrastructure, lack of resources and this not common to all schools, thereby resulting in digital divide. Under-resourced and rural schools have no capacity to equip laboratories for programming programmes and other ICT learning activities [1], [60], [62], [63]. This becomes a challenge as students pursuing programming or coding needs to have a one-to-one ratio in terms of gadgets, even if the work sometimes needs collaborations, for a teacher to evaluate the progress of each student, some tasks need to be done individually [51], [53], [55], [59], [60]

How to teach? This question requires teachers to choose the most appropriate approaches to engage with students so that basic programming concepts are introduced to students, bearing in mind that basic principles lay a foundational anchor

to students' future learning activities in that area. In the previous section we discussed the learning difficulties students may face during the implementation of program/coding courses. This is one of the reasons we may need to find the best methods of engaging the students and we also seek to find ways of hooking students' motivation in an engaging and effective way [37]. This question prompted us to develop RQ 2: *What teaching methods and tools are being used to introduce basic programming concepts in preparation for AI, AR and VR learning?* The study is based on primary schools in S.A and age ranges are approximately from 4,5 years to 13 years. This group of students enjoy much of their time in playing, so most of the teachers who teach these groups apply play and game-based teaching, [19], [51], [54], [62], [63], [65], on top of teacher-based instructions [59], [60] and collaborations [55], [56], [57]. In addition, for assessment purposes, individual assignments are given to awaken the inner ability of each child [1], [55], [68].

Tools that were mentioned by most studies are scratch [19], [51], [53], [54], [61], [67] and TANKS [62], [63], [65], although some authors did mention other additional tools [51], [54], [55], [56], [57], [67], [68], TANKS was regarded as best tool to be applied in schools that are under resourced and rural schools, where school authorities are finding it difficult to improve their infrastructures and build laboratories with state-of-the-art equipment, [62], [63]. The interesting part is that, in as much as students are being prepared to develop the AI/AR/VR applications and gadgets, those applications are already teaching them the basics of programming/coding [54], [56], [57], [67], [68].

The current study in comparison with extant systematic reviews offers three distinct contributions. Initially it provides a geographically grounded analysis focused on primary schools in SA, thereby addressing the underrepresentation of Global South contexts in the literature. Second, it moves beyond isolated discussion of computational thinking by integrating programming education with the discourse of AI/AR/VR. Third, to shape educational practices and outcomes, the study foregrounds the role of context resource disparities, to align pedagogical systems with the demands of 4IR.

VI. LIMITATIONS AND FUTURE STUDY

The system literature review tried to inherently limit the scope of analysis to existing scholarly articles published in Scopus journal articles but due to limited sources published about the programming in primary schools maybe due to the fact that curriculum that support the teaching was initiated in 2021 and the implementation started 2023 and is still in progress, the study had to extend the search to google scholar and include documents such as government policies and theses and book chapters as a result.

Future research would delve into the actual empirical investigation of basic programming principles in education in primary schools and investigating the actual programming concepts taught to develop AI/AR/VR technologies.

VII. CONCLUSION

South African primary school education is gradually taking programming principles into their teaching practises. However, the slow uptake in most under-resourced and rural schools is caused by poor infrastructure and lack of resources, in Schools that have better resources teachers had already started teaching programming using informal curricular, curricular from private organisations or from online websites even before the official curriculum was rolled out by the government. The findings highlight the programming tools that are adopted by teachers who work in different backgrounds, for example the low resourced and rural areas are taking TANKS mostly as their tools, while they prefer to have game-based teaching method to motivate their students. Whereas those in better resourced are using a wide range of tools for programming and the learning methods range from collaborations, games and individual assignments.

The DBE with its initiative of including coding and robotics into its curricular has shown great commitment to enhance the quality of primary schools in S.Aas this is in line with sustainable goal number 4 and African Union Agenda 2063. Although this is still in early stages and would want to be managed well so that the issue of digital divide will not be worsened as the gap between the well-resourced and the low resourced primary school widen.

The questions stated in this review paper were addressed satisfactorily which gives the study the coherence guided by the PCK theory declared to anchor the study. The theory proposed 4 questions “*why teach a certain subject? what should be taught? what are the learning difficulties? and how to teach?*” [37], which were used in our thematical discussion of the findings. From the data extracted tables in supplementary file all the questions were answered and represented, and those answers are linked to the answer of the next question for example the tools used for teaching such as TANKS involves programming concepts like sequences, and sequences are essential in problem solving skills which is part of computational skills and this coding game is an unplugged coding concepts which can be used by both low resourced and well-resourced group of schools.

The study acknowledges some limitations and the study recommended the empirical investigations so that literature on the programming in primary schools can be increased, on top of the future research the authors are curious to know if schools are teaching AI in education only or they are also engaging in education for AI and its related tools.

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