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Rethinking Programming Pedagogy amid the Digital Divide: Resources, Appropriation, and Agency in Ekurhuleni Township Schools

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ABSTRACT

This study explores how Information Technology teachers in Ekurhuleni township schools navigate the complex interplay between digital inequality and programming pedagogy. Although programming has been integrated into the national curriculum through the Curriculum and Assessment Policy Statement (CAPS) framework, its implementation remains shaped by enduring inequalities in infrastructure, digital literacy, and teacher support. Anchored in an interpretivist paradigm and framed by Resources and Appropriation Theory (RAT) and the Technological Pedagogical Content Knowledge framework (TPACK), the study adopted a qualitative case study design. Four teachers from townships in the Ekurhuleni municipality were purposively selected. Data was collected through semi-structured interviews and classroom observations and was reflexively analysed thematically. Findings reveal that programming teachers routinely confront structural challenges, including unreliable connectivity, insufficient devices, and varying learner competencies. However, they exercise agency through adaptive pedagogical strategies such as contextualised instruction, collaborative learning, and structured problem-solving. The findings call for equity-oriented curriculum reform, increased investment in digital infrastructure, and ongoing teacher support in historically disadvantaged contexts. These strategies mediate the effects of material access and support the development of computational thinking. The study is relevant to current debates on digital inequality. It contributes to scholarship by shifting the focus from deficit-based digital divide narratives to teacher-led adaptations within marginalised learning environments.

Keywords: Computational Thinking, Digital Divide, Programming Pedagogy, Teacher Agency, Township Schools.

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INTRODUCTION

As technology advances by leaps and bounds, programming has emerged as a vital skill not only for careers in science and technology but also for developing critical thinking and problem-solving abilities across various disciplines. Educational systems worldwide respond to this demand by integrating programming into school curricula. This shift is based on the growing recognition that computational thinking, which involves abstraction, decomposition, debugging, and algorithmic design, equips learners with transferable cognitive skills.[1] As a result, programming education is now viewed as a

[1] Jeannette M. Wing, "Computational Thinking," *Communications of the ACM* 49, no. 3 (March 2006): 33–35, https://doi.org/10.1145/1118178.1118215.

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foundational component of 21st-century learning.[2] However, the global emphasis on programming education brings complex questions about access, equity, and implementation in contexts where the foundational conditions for teaching programming are unevenly distributed.[3]

Although the global education agenda promotes programming as universally valuable, the capacity of countries to implement this vision varies extensively. In developed systems, programming education is supported by advanced infrastructure, professional teacher development, and learner access to digital technologies.[4] In many developing contexts, implementation is hindered by structural challenges, such as inadequate infrastructure, limited teacher expertise, and poor access to devices and connectivity.[5] These disparities reveal a critical tension in which programming is promoted as a universally important subject, yet highly unequal material conditions shape the reality of its delivery. This tension raises concerns about how global curriculum initiatives are translated into practice in under-resourced environments.[6]

Across Africa, efforts to include programming in school curricula are growing, often driven by national ICT policies aimed at digital transformation.[7] Countries like Kenya, Nigeria, and Rwanda have outlined strategic plans for integrating technology into education systems. South Africa is among these nations, having developed a firm policy and strategic frameworks for digital education. However, the shift from policy to practice is far from seamless. In countries like Tanzania, it is challenging due to various reasons, mainly related to socioeconomic and environmental factors, such as inadequate infrastructure, out-of-date materials, staff with insufficient training, ineffective instructional approaches, learners from disadvantaged educational backgrounds, inconsistent and limited access to electricity, cultural diversity, substandard living conditions, poverty, and inability to purchase computers for personal use.[8] These constraints are not isolated but reflect broader sociopolitical and socioeconomic inequities that continue to shape instruction across the continent.

These challenges are exemplified in South Africa due to the country's historical and structural inequalities. The legacy of apartheid has produced an unequal education system, in which resource allocation continues to reflect patterns of spatial and economic segregation. Township schools, which primarily serve historically disadvantaged communities, often lack basic digital infrastructure such as computer laboratories, updated devices, and stable internet access.[9] These infrastructural deficits are compounded by learners' diverse socioeconomic backgrounds, which influence their digital exposure and readiness levels.[10] For teachers in these settings, teaching programming involves more than content delivery; it involves addressing their learners' varying levels of digital literacy in the shadow of the landscape historically marked by digital exclusion and pedagogical complexity.

Recognising these systemic challenges, the South African Department of Basic Education (DBE) has introduced various initiatives to support the implementation of programming in schools.

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[2] Héctor Belmar, "Review on the Teaching of Programming and Computational Thinking in the World," *Frontiers in Computer Science* 4 (October 19, 2022), https://doi.org/10.3389/fcomp.2022.997222.

[3] Ashley Rea, "Coding Equity: Social Justice and Computer Programming Literacy Education," *IEEE Transactions on Professional Communication* 65, no. 1 (March 2022): 87–103, https://doi.org/10.1109/TPC.2022.3143965.

[4] Lijun Ni, Gillian Bausch, and Rebecca Benjamin, "Computer Science Teacher Professional Development and Professional Learning Communities: A Review of the Research Literature," *Computer Science Education* 33, no. 1 (January 2, 2023): 29–60, https://doi.org/10.1080/08993408.2021.1993666.

[5] Salmiah Salleh Hudin, "A Systematic Review of the Challenges in Teaching Programming for Primary Schools' Students," *Online Journal for TVET Practitioners* 8, no. 1 (2023): 75–88.

[6] Mashite Tshidi and Alton Dewa, "The Promise and Peril of Coding & Robotics Education in South Africa: A Scoping Review of Teacher Preparation and Generative Artificial Intelligence's Potential for Delivering Equity," *Journal of Education*, no. 96 (November 12, 2024): 141–64, https://doi.org/10.17159/2520-9868/i96a08.

[7] Alcardo Alex Barakabitze et al., "Transforming African Education Systems in Science, Technology, Engineering, and Mathematics (STEM) Using ICTs: Challenges and Opportunities," *Education Research International* 2019 (February 3, 2019): 1–29, https://doi.org/10.1155/2019/6946809.

[8] Themba Ralph Mkhlze and Mogamat Noor Davids, "Towards a Digital Resource Mobilisation Approach for Digital Inclusion During COVID-19 and Beyond: A Case of a Township School in South Africa," *Educational Research for Social Change* 10, no. 2 (September 1, 2021): 18–32, https://doi.org/10.17159/2221-4070/2021/v10i2a2.

[9] Mkhlze and Davids, "Towards a Digital Resource Mobilisation Approach for Digital Inclusion During COVID-19 and Beyond: A Case of a Township School in South Africa."

[10] Ramon Mayor Martins and Christiane Gresse von Wangenheim, "Teaching Computing to Middle and High School Students from a Low Socio-Economic Status Background: A Systematic Literature Review," *Informatics in Education*, May 24, 2023, https://doi.org/10.15388/infedu.2024.01.

These include partnerships with organisations, such as Code College, CodeX, and CodeSpace, which aim to improve teacher training and equip educators with the skills necessary to teach coding and programming.[11] However, the efficacy of these interventions is hampered by the broader systemic issues that shape classroom realities. Teachers grapple with inadequate infrastructure, inconsistent learner engagement, and wide disparities in digital literacy levels.[12] These conditions limit the potential impact of professional development and highlight the importance of understanding teachers' everyday experiences within these constraints.[13]

Despite the growing interest in digital education and equity, there remains limited research on how programming is taught in under-resourced South African schools and how teachers adapt their practices to address their challenges. This study responds to that gap by exploring the perspectives of Information Technology (IT) teachers who teach programming to secondary school learners in township contexts. The study focuses on the practical challenges and the pedagogical strategies used by these teachers to navigate them and support learner engagement. To guide this investigation, the study is framed by the following research questions:

1. What are programming teachers' most significant challenges when teaching programming to learners in under-resourced contexts?
2. What pedagogical strategies do these teachers adopt to overcome or navigate these challenges?

CONCEPTUAL FRAMEWORK

A conceptual framework is a series of tangible and connected concepts that coherently structure an inquiry.[14] These concepts are not distinct; their significance is found in how they are organised, linked, and centred on the phenomenon being investigated. This study draws on two interrelated conceptual lenses, Van Dijk's Resources and Appropriation Theory (RAT) and the Technological Pedagogical Content Knowledge (TPACK) framework, to examine how programming education unfolds in South African township schools under conditions of digital inequality.

RAT is based on the understanding that access to technology is dictated by long-standing social structures rather than solely individual choices or device availability. The theory is predicated on the notion that the unequal distribution of resources required for meaningful engagement with digital technologies is caused by categorical inequalities structured along lines like class, race, gender, and geography.[15] These inequalities are generative and systemic, shaping not only what is accessible but also who is entitled to benefit from it.[16]

From that vantage point, access is a multi-level and dynamic process rather than a single occurrence. Having digital tools or material access is only one component. Skills, motivation, and contextual support are necessary to use these technologies (*ibid*). Technology is also not neutral; certain users may benefit from its functionality, design, and underlying presumptions while others may not. As a result, access is relational, relying on the demands of the technological artefact and the user's position within social structures (*ibid*).

Unequal access has technical, social, and epistemic implications. When individuals cannot use digital platforms or practices, they become restricted in their ability to participate in significant domains

[11] K. C. Cheruiyot and K. J. Chepngetich, "Culture in Design of Coding Toolkits for Young Learners in Developing Economies in Africa: A Review," *Current Journal of Applied Science and Technology* 42, no. 24 (2023): 43–50

[12] Koech Charles Cheruiyot and Koech Janeth Chepngetich, "Culture in Design of Coding Toolkits for Young Learners in Developing Economies in Africa: A Review," *Current Journal of Applied Science and Technology* 42, no. 24 (August 14, 2023): 43–50, https://doi.org/10.9734/cjast/2023/v42i244177.

[13] Ni, Bausch, and Benjamin, "Computer Science Teacher Professional Development and Professional Learning Communities: A Review of the Research Literature."

[14] Navé Wald and Ben Kei Daniel, "Enhancing Students' Engagement with Abstract Ideas through Conceptual and Theoretical Frameworks," *Innovations in Education and Teaching International* 57, no. 4 (July 3, 2020): 496–505, https://doi.org/10.1080/14703297.2019.1692055.

[15] Frans van Dijk and Frans van Dijk, "Judicial Independence and Perceptions of Judicial Independence," *Perceptions of the Independence of Judges in Europe: Congruence of Society and Judiciary*, 2021, 7–28.

[16] Alexander JAM van Deursen and Jan AGM van Dijk, "The First-Level Digital Divide Shifts from Inequalities in Physical Access to Inequalities in Material Access," *New Media & Society* 21, no. 2 (February 7, 2019): 354–75, https://doi.org/10.1177/1461444818797082.

such as civic life, education, and employment.[17] In the long run, these limited participation patterns reinforce the categorical inequalities that led to them.[18] The digital divide is a recursive loop of social exclusion woven across digital societies rather than just a difference in ownership or connectivity.

In South Africa, apartheid spatial planning, uneven school funding, and broader socioeconomic disparities have affected how digital technologies are distributed in schools. Township schools often face infrastructure challenges such as unstable power, inadequate internet speed, and out-of-date hardware.[19] However, access is not limited to the physical availability of digital technologies. Van Dijk defined access as multifaceted, including attitude access (motivation and belief in utility), material access (devices and infrastructure), skills access (technical proficiency), and usage access (an opportunity to participate meaningfully).[20] These levels represent the first, second, and third stages of the digital divide, which show a growing hierarchy of inequality, from simply owning a device to being proficient with it and reaping the benefits of its use.[21] Each level presents a new exclusion layer, determining how programming education unfolds in under-resourced contexts.[22]

Although the RAT clarifies the macrostructural factors that inhibit learning possibilities, it does not account for how teachers respond to the learning of their students in the classroom. The study addresses this by overlaying the TPACK framework, which is made up of three knowledge domains that overlap: pedagogical knowledge (the way that knowledge is taught), technological knowledge (the instruments that are used to teach), and content knowledge (what is taught).[23]

The overlay of this framework on RAT creates a relationship of constraints and response, where teachers incorporate and modify TPACK in response to structural inequalities that limit what is pedagogically possible.[24] This is not a uniform or passive response. Individual teacher training, previous experience, professional networks, and resourcefulness shape it.[25] Some can capitalise on pedagogical flexibility to compensate for limited resources, while others could be overwhelmed by systemic challenges. The TPACK framework can examine these distinct responses.[26]

The relationship between structural constraints and professional agency is non-linear. Instead, it is interactively layered, with access limitations resulting from macro-level inequalities compromising the viability of various methods of instruction.[27] These are then filtered by teachers' TPACK, which helps them make decisions about their daily instruction. These classroom-level alterations contribute to learners' opportunities to interact meaningfully with programming and digital tools, their ability to develop computational thinking, and their broader digital empowerment.[28] Therefore, the conceptual framework of this study captures the pedagogical granularity of teacher responses and the structural depth of digital inequality.

METHODOLOGY

Anchored in the interpretivist paradigm, this study employed a qualitative case study design to explore how programming teachers in township schools perceive and respond to structural and pedagogical challenges associated with digitally constrained environments. Since reality is socially constituted and

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[17] Makhulu A Makumane and Cedric Bheki Mpungose, "Digital Divide: Secondary School Learners' Experiences of Using Educational Technologies.," *Alternation*, 2022.

[18] van Dijk and van Dijk, "Judicial Independence and Perceptions of Judicial Independence."

[19] T. R. Mkhlze and M. N. Davids, "Towards a Digital Resource Mobilisation Approach for Digital Inclusion during COVID-19 and Beyond: A Case of a Township School in South Africa," *Educational Research for Social Change* 10, no. 2 (2021): 18–32

[20] JAGM Van Dijk, "Digital Divide: Impact of Access," *The International Encyclopedia of Media Effects* 1 (2017): 1–11.

[21] van Deursen and van Dijk, "The First-Level Digital Divide Shifts from Inequalities in Physical Access to Inequalities in Material Access."

[22] Rea, "Coding Equity: Social Justice and Computer Programming Literacy Education."

[23] P. Mishra and M. J. Koehler, "Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge," *Teachers College* **Record** 108, no. 6 (2006): 1017–1054

[24] Van Dijk, "Digital Divide: Impact of Access."

[25] L. Ni, G. Bausch, and R. Benjamin, "Computer Science Teacher Professional Development and Professional Learning Communities: A Review of the Research Literature," *Computer Science Education* 33, no. 1 (2021): 29–60

[26] Brian Shambare and Clement Simuja, "Unveiling the TPACK Pathways: Technology Integration and Pedagogical Evolution in Rural South African Schools," *Computers and Education Open* 7 (December 2024): 100206, https://doi.org/10.1016/j.caeo.2024.100206.

[27] Makumane and Mpungose, "Digital Divide: Secondary School Learners' Experiences of Using Educational Technologies."

[28] Kathy A. Mills et al., "Coding and Computational Thinking Across the Curriculum: A Review of Educational Outcomes," *Review of Educational Research* 95, no. 3 (June 2025): 581–618, https://doi.org/10.3102/00346543241241327.

context-dependent, interpretivism posits that knowledge is co-produced through interactions between researchers and their subjects.[29] This ontological and epistemological position is consistent with the study's conceptual drive to understand how the digital divide, formed by structural inequalities, interacts with teachers' instructional agency by integrating TPACK in programming education. As *ibid* argues, social realities can be effectively understood through the meanings individuals assign to them, thus making teachers' perspectives central to this inquiry.

In this setting, the case study design functioned as a means of inquiry and a tool for developing context-sensitive knowledge. Focusing on teachers in under-resourced township schools, the study highlighted the micro-level pedagogical decisions and adaptive strategies often obscured in deficit-oriented digital divide discourses. Since case study research combines several data sources to comprehend a bounded system in its actual environment, it is ideal for this type of inquiry.[30] Thus, the design enabled the dual objectives of the study of spotlighting how structural inequalities limit programming education and highlighting teachers' localised approaches to address these challenges.

Four teachers who teach programming from four township high schools were treated as distinct cases bound in the Ekurhuleni municipality. They were purposefully chosen based on their experience in instructing IT to obtain these viewpoints. The CAPS curriculum in South Africa exposes learners to foundational programming through the IT subject. The teachers were chosen not only for their subject-matter knowledge but also because they were embedded in historically marginalised learning spaces shaped by socioeconomic pressures, enduring infrastructure deficiencies, and disparities from the apartheid era.[31] The sociocultural, political, and ideological context in which they operate as professionals shapes how programming is taught and experienced in township classrooms.[32] The study's conceptual framework sees research as a generative site of meaning-making.[33] These participants were considered situated knowers negotiating the intersections of systemic constraint and pedagogical exertion rather than as neutral data providers.

The data-collection process was intended to capture how institutional and personal identities shape professional judgement, how historical contexts continue to impact contemporary educational realities, and how macro-sociopolitical factors manifest themselves in day-to-day programming instruction. The primary data collection approach was semi-structured interviews, which were selected due to their ability to balance thematic direction and the flexibility required to accommodate teachers' narratives, situated meanings, and contextual knowledge.[34] These in-person interviews were held in the participants' classrooms and lasted between forty-five and sixty minutes apiece. The interviews in these familiar locations provided greater contextualisation and reduced the epistemic distance between the researcher and the participant.[35] Classroom observations were also conducted during programming lessons to document the material and embodied facets of teaching in township settings. The observation centred on the resources provided and their use in pedagogical practices. Using a critical-intersectional lens, the observations focused on infrastructural conditions, socio-technical improvisation, and how digital inequity was interpreted and managed during the teaching process.[36] As a result of focusing on using these data collection approaches as a relational, trustworthy, and socially aware practice, the study ensured that perspectives were not extracted but co-constructed in ways that respected teachers' expertise and positions.

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[29] Leah S. Muccio et al., "Head Start Instructional Professionals' Inclusion Perceptions and Practices," *Topics in Early Childhood Special Education* 34, no. 1 (May 24, 2014): 40–48, https://doi.org/10.1177/0271121413502398.

[30] Priyabrata Patra et al., "Intimate Partner Violence: Wounds Are Deeper," *Indian Journal of Psychiatry* 60, no. 4 (2018): 494–98.

[31] Mkhlze and Davids, "Towards a Digital Resource Mobilisation Approach for Digital Inclusion During COVID-19 and Beyond: A Case of a Township School in South Africa."

[32] Lydia Mavuru and Umesh Ramnarain, "Learners' Socio-Cultural Backgrounds and Science Teaching and Learning: A Case Study of Township Schools in South Africa," *Cultural Studies of Science Education* 15, no. 4 (December 18, 2020): 1067–95, https://doi.org/10.1007/s11422-020-09974-8.

[33] Makumane and Mpungose, "Digital Divide: Secondary School Learners' Experiences of Using Educational Technologies."

[34] Margie Burns et al., "Constructivist Grounded Theory or Interpretive Phenomenology? Methodological Choices Within Specific Study Contexts," *International Journal of Qualitative Methods* 21 (April 26, 2022), https://doi.org/10.1177/16094069221077758.

[35] Arya Priya, "Case Study Methodology of Qualitative Research: Key Attributes and Navigating the Conundrums in Its Application," *Sociological Bulletin* 70, no. 1 (January 19, 2021): 94–110, https://doi.org/10.1177/0038022920970318.

[36] Makumane and Mpungose, "Digital Divide: Secondary School Learners' Experiences of Using Educational Technologies."

The interview transcripts and observational notes were reflexively analysed thematically. Using Braun and Clarke's six-phase model, the analysis went through familiarisation, initial coding, theme development, refining, naming, and reporting.[37] The process, which was iterative and dialogic rather than treating themes as fixed entities, underscored the dynamic interplay between the researcher's lens, participants' meaning-making, and the socio-material environment in which they are situated. Deductive and inductive coding techniques were applied. Meanings based on their specific contexts emerged due to the inductive codes created from the teachers' narratives and firsthand accounts. Conversely, the RAT informed deductive coding, showing how infrastructure, pedagogical adaptation, and access challenges arise in historically disadvantaged schools. Analysing the data was thus about interpreting lives lived in unequal structures and disclosing how teachers exercise agency within and outside the digital divide's constraints.

The University of the Witwatersrand research ethics committee approved this study, and the Gauteng Department of Education formally approved access and participation with selected schools. All participants were aware of the objectives of the study, procedures, and rights. Given the sensitive nature of the matter, which includes structural injustices, professional vulnerability, and institutional resource gaps, the ethical approach extended beyond procedural compliance. It prioritised relationship accountability, empathy, and dignity. Confidentiality was maintained by using pseudonyms for all participants and schools, and the researcher made it clear that the study's goal was not to evaluate teaching competence, but to amplify teachers' voices in contexts dominated by historical structural disadvantage. Further ingrained in ethical practice was the researcher's reflexive procedure, which recognised power disparities, respected participants' intellectual agency, and aimed to co-construct knowledge in a way that was contextually grounded, non-extractive, and attentive to crucial issues.

PRESENTATION AND DISCUSSION OF FINDINGS

The findings of the study are discussed using themes that emanated from a grounded interaction with the data (inductive reasoning) and those that were predetermined through the conceptual lenses of RAT and the TPACK framework (deductive reasoning). The themes are presented in a narrative style to remain credible and preserve the authenticity of the teachers' experiences.[38]

Theme 1: Material and usage access

The issue of material and usage access to ICTs emerged as a dominant theme from classroom observations and interviews. Teachers pointed out an absence of functional computers and inconsistent internet access, which challenged teaching and learning programming. As Teacher A explained:

> "We have two computer labs, but over half the computers do not work. And when we have load shedding and electricity going off, the whole system is down, and we cannot do anything for days."

This statement identifies multiple challenges, including faulty machines, inadequate maintenance, and power outages. These challenges limit material access and underscore the multi-layered digital divide in the township context. In South Africa, load shedding is a systemic concern that involves planned power outages, adding a barrier that is often overlooked in global models of digital access.[39] As Teacher C elaborated:

> "When we have load shedding, we are stuck. I try to teach theory, but it feels pointless without the computers. The learners cannot grasp programming concepts without practising on the machines, and we end up falling behind on the syllabus."

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[37] Virginia Braun and Victoria Clarke, "Thematic Analysis: A Practical Guide," 2021.

[38] Makumane and Mpungose, "Digital Divide: Secondary School Learners' Experiences of Using Educational Technologies."

[39] Novel Lena Folabit, Loyiso C. Jita, and Thuthukile Jita, "Impact of Technology Integration on Students' Sense of Belonging and Well-Being: A Systematic Review," *International Journal of Evaluation and Research in Education (IJERE)* 14, no. 2 (April 1, 2025): 1075, https://doi.org/10.11591/ijere.v14i2.30938.

In the context of TPACK, this hinders teachers' capacity to integrate technology into their pedagogical practice and lowers the efficacy of content delivery.[40] Along with hardware malfunctions, internet access remains poor and inconsistent. Teacher B remarked:

> "Our school has Wi-Fi, but the connection in the labs is slow and keeps cutting out. This makes it hard to use the online resources we need for programming."

This reinforces the RAT's usage access restrictions. The cumulative effect of poor internet connectivity and infrastructure failure compromises teachers' pedagogical opportunities to execute programming instruction effectively. Teachers are often forced to revert to theoretical instruction, which, although essential for basic understanding, hinders learners' capacity to develop practical programming expertise.

Furthermore, even when access is restored, the window for practical instruction is constrained by the time constraints imposed by unstable electricity and the internet. Active, iterative engagement is essential for effectively executing programming instructions.[41] Teacher B's statement echoes this:

> "It is heartbreaking when the exams come, and the learners do not have enough practical experience. They know basic programming concepts like loops and variables, but struggle to apply them in practical scenarios."

This is when the gap between practical application and topic knowledge is evident. When digital resources are not consistently available, the TPACK framework is disrupted; the pedagogical approach needs to be restructured, often at the expense of the learning experience.[42] These findings suggest that physical and material access remain foundational challenges with far-reaching pedagogical and epistemological implications.

Theme 2: Pedagogical adaptations and TPACK application

In response to infrastructure constraints, teachers noted a variety of pedagogical adaptations designed to ensure that programming education remains meaningful. These approaches reflect the teachers' capacity to integrate pedagogical procedures, content knowledge, and technological tools. Simultaneously, these adaptations reflect skills and usage access, wherein the ability to use digital tools consciously implies increased engagement.[43]

Teachers favoured programming languages that could adapt to erratic internet access. Due to its accessibility and user-friendliness, Delphi, a platform that does not require a license, became the instrument of choice. Teacher D stated:

> "I have had to teach IT using different programming languages, but I mostly prefer Delphi. Its interface and codebase are easy to use. Some learners download it without asking for the school's login details, so they can keep working on their practice tasks at home if there is a computer."

The example illustrates how teachers use offline-compatible, low-bandwidth technologies to facilitate continuous engagement.[44] In this context, teachers also emphasised algorithmic thinking as a foundational skill, often employing a structured approach to problem-solving. Teacher A outlined a six-step method:

> "At Grade 10, learners enter the subject without a conceptual foundation of programming. To develop algorithmic thinking, I emphasise the six steps of problem-

[40] Shambare and Simuja, "Unveiling the TPACK Pathways: Technology Integration and Pedagogical Evolution in Rural South African Schools."

[41] Jane Waite and Sue Sentance, "Teaching Programming in Schools: A Review of Approaches and Strategies," *Raspberry Pi Foundation,* 2021, 1–53.

[42] Eliana Brianza et al., "Is Contextual Knowledge a Key Component of Expertise for Teaching with Technology? A Systematic Literature Review," *Computers and Education Open* 7 (December 2024): 100201, https://doi.org/10.1016/j.caeo.2024.100201.

[43] van Deursen and van Dijk, "The First-Level Digital Divide Shifts from Inequalities in Physical Access to Inequalities in Material Access."

[44] Rea, "Coding Equity: Social Justice and Computer Programming Literacy Education."

> solving: (1) defining the problem, (2) understanding the problem, (3) applying decomposition, (4) planning the logic, (5) using solution development tools like IPO models and flowcharts, and (6) creating an algorithm."

This systematic approach depicts how teachers scaffold problem-solving in ways that foster computational thinking and correspond to both the pedagogical and content aspects of TPACK.[45] Contextualised learning was also essential as teachers sought to bridge the gap between abstract programming concepts and practical application. Teacher B explained how they used regular instances to demonstrate problem decomposition:

> "I use everyday examples for them, like before you cook, you know that you need to follow the recipe first... So, I then ask them, 'How do you bake the cakes?' What is it that you need?"

These examples demonstrate the strategic use of context to reinforce learners' mental models and aid in the development of algorithmic logic.[46] Teacher C framed problem-solving in light of recent events:

> "I design our programming lessons around what is happening in our country to improve their problem-solving skills. For example, during election season, I had my grade 10 learners work in pairs to write a program for online voting and recording votes. Similarly, when we faced problems with the license booking system, where people struggled to book driver's license tests online, we developed a smaller program to address this issue."

This practice reflects findings on pedagogical awareness of learners' contexts and supports programming integration into meaningful, socially oriented activities.[47] Peer collaboration also emerged as a key pedagogical approach. Teacher C laid out:

> "When teaching a new programming concept, one learner will immediately catch it... Once he is done, he assists others. I also use pair work and walk around to see their progress."

This type of collaboration regulates teamwork and peer support, which helps with access to content mastery, skills, and attitude. Similar study findings indicate that collaborative learning promotes computational thinking growth and learner autonomy in resource-constrained contexts.[48] This exemplifies how access intersects with pedagogical design to promote inclusive classroom participation.[49]

Teachers also adapted their instruction to bridge the gaps in computing, as many learners in these schools enter the IT stream with minimal computing experience. Teacher A shared:

> "At Grade 10, I teach them how to use a computer because many have never used one. I teach them how to type, and once they get comfortable typing, they move faster when we start coding programs."

This approach suggests an awareness of skill access, in which learners first gain basic operational literacy before moving on to challenging programming tasks.[50] Another educator engaged students by using the Delphi integrated development environment's visual manipulation features:

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[45] Belmar, "Review on the Teaching of Programming and Computational Thinking in the World."

[46] Chin Soon Cheah, "Factors Contributing to the Difficulties in Teaching and Learning of Computer Programming: A Literature Review," *Contemporary Educational Technology* 12, no. 2 (May 8, 2020): ep272, https://doi.org/10.30935/cedtech/8247.

[47] Cheruiyot and Chepngetich, "Culture in Design of Coding Toolkits for Young Learners in Developing Economies in Africa: A Review."

[48] Martins and Gresse von Wangenheim, "Teaching Computing to Middle and High School Students from a Low Socio-Economic Status Background: A Systematic Literature Review."

[49] Belmar, "Review on the Teaching of Programming and Computational Thinking in the World."

[50] Folabit, C. Jita, and Jita, "Impact of Technology Integration on Students' Sense of Belonging and Well-Being: A Systematic Review."

> "I have them insert a form, adjust the colour, height, and width, and make visual changes. This gets them excited, and from there, we move into coding."

These measures facilitate attitude access. Learners' connection to the content catalyses increased engagement, thereby supporting the technological and content components of TPACK while fostering motivational and attitude access.

Theme 3: Teacher agency in addressing digital inequality
Despite structural limitations in township schools, teachers described how they could mediate digital inequality through TPACK-informed practices and proactive access approaches. Constraints on digital resources led to individual agentic approaches to content distribution. Teachers selected video materials and instructional files and distributed them on USB devices for offline use. Teacher B stated:

> "I download coding exercises, tutorials from Code.org, and videos for them and load them onto the drives. This way, they can practice even when not in class."

These methods address material access concerns while improving usage access by enabling learners to interact with content frequently and independently.[51]
Collective agency was reflected in teachers' interactions with external stakeholders and school management. Open Educational Resources (OERs), including digital textbooks and coding data files, were made available through the DBE initiatives, including those sponsored by the MTN SA Foundation. Teacher C went on to explain:

> "We use this eBook from MTN, which comes with data files and guided activities... I get them to do a guided activity in class or as homework. It is a great way to make sure they are practising what we have just covered."

These OERs enrich classroom practice by reinforcing skills and usage access. Teachers also participated in district-specific professional development programs, which improved their TPACK skills and helped them keep up with expanding policies, such as incorporating Coding and Robotics into the national curriculum.[52] Participation in these communities of practice reflects the growth mindset and teachers' desire to face structural problems head-on. As one would argue, agency in digitally unequal contexts is most understood as individual resilience and a collective pedagogical commitment to educational justice.[53]

RECOMMENDATIONS

Given these findings, educational policy must address the layered and systemic nature of digital inequality. Interventions must move beyond infrastructure provisioning to include pedagogical and curricular scaffolds that foster meaningful engagement. This includes ensuring consistent access to hardware, stable connectivity, and sustained training in computing. The ongoing pilot of the Coding and Robotics curriculum is promising, but aligning it with the IT subject at the Grades 10-12 level is necessary. A progression from block-based to text-based programming would enable cognitive transfer and support the development of stable mental models.[54]

For schools, sustained teacher development should be prioritised to strengthen digital pedagogy, particularly in relation to differentiated instruction and the facilitation of collaborative learning. Schools should also provide opportunities to support peer-assisted learning while ensuring that learners continue to develop independent computing skills.

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[51] Makumane and Mpungose, "Digital Divide: Secondary School Learners' Experiences of Using Educational Technologies."
[52] Ni, Bausch, and Benjamin, "Computer Science Teacher Professional Development and Professional Learning Communities: A Review of the Research Literature."
[53] Mkhlze and Davids, "Towards a Digital Resource Mobilisation Approach for Digital Inclusion During COVID-19 and Beyond: A Case of a Township School in South Africa."
[54] Cheah, "Factors Contributing to the Difficulties in Teaching and Learning of Computer Programming: A Literature Review."

For teachers, the findings highlight the value of improvisational and context-sensitive strategies.[55] Practices such as contextualising programming tasks within learners' social realities, encouraging collaborative learning, and scaffolding complex concepts through decomposition and flowcharting should be refined and systematically embedded in teaching approaches. Teachers should also be supported to integrate game-based learning and culturally responsive computing methods in ways that sustain motivation while reinforcing conceptual understanding.

For researchers, this study's reliance on teacher-reported data presents limitations. Future research should integrate teacher accounts with learners' direct experiences and classroom observations to examine how pupils internalise and apply computational thinking skills across instructional modalities. Expanding research to include a wider range of schools would also strengthen the generalisability of findings.

CONCLUSION

This study investigated how IT teachers in under-resourced South African township schools deal with the pedagogical and infrastructure problems of teaching programming. Anchored in the RAT and TPACK frameworks, it explored how teachers' practices engage learners in the context of persistent digital inequality. The findings indicate that despite significant constraints, teachers often adopt flexible, improvisational strategies to foster computational thinking. These include collaborative learning, contextualised instruction, structured problem-solving, and adaptive scaffolding. These strategies encouraged learner participation and reflected a pedagogical intent to develop algorithmic reasoning. The use of decomposition and flowcharting is consistent with existing literature on their value in building learners' cognitive programming models.

However, these efforts were tempered by systemic challenges. Teachers had to substantially differentiate instruction due to learners' varied prior exposure to digital tools. This aligns with evidence that students from digitally marginalised contexts often require foundational computing support before engaging meaningfully with abstract coding concepts.[56] Notably, the lack of block-based programming at earlier levels of schooling emerged as a systemic limitation, putting pressure on teachers to introduce text-based environments such as Delphi.

Teachers also highlighted the importance of contextualising programming tasks within learners' social realities. In line with culturally responsive computing frameworks, these strategies effectively bridge abstract coding concepts with the lived experiences of learners, improving motivation and conceptual understanding.[57] Collaborative learning was a frequently employed response to differing learning paces. Recognising that some learners acquired fluency rapidly while others had difficulty, teachers often promoted peer-assisted learning. Although this approach encouraged social learning and distributed problem-solving, it also increased the risk of reliance, making less effective learners dependent on peers rather than gaining independent computing skills. As the literature indicates, co-constructed learning environments must be supported by planned facilitation to demonstrate that collaborative engagement promotes cognitive development rather than concealing underlying misconceptions.[58]

Despite these adaptive pedagogical practices, the study underscores township schools' entrenched curricular and infrastructural limitations. Material access remains uneven, and motivational access is undermined by the abrupt introduction to computing in Grade 10, with little prior exposure. Teachers' efforts to spark interest through game-based learning and interface manipulation were meaningful, but could not compensate for the legacy of underexposure and digital seclusion.

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[55] Brianza et al., "Is Contextual Knowledge a Key Component of Expertise for Teaching with Technology? A Systematic Literature Review."

[56] Cheruiyot Chepngetich and, "Culture in Design of Coding Toolkits for Young Learners in Developing Economies in Africa: A Review."

[57] Brianza et al., "Is Contextual Knowledge a Key Component of Expertise for Teaching with Technology? A Systematic Literature Review."

[58] Martins and Gresse von Wangenheim, "Teaching Computing to Middle and High School Students from a Low Socio-Economic Status Background: A Systematic Literature Review."

In general, this study underscores the ingenuity and adaptability of teachers working under conditions of digital and material scarcity. However, it also makes visible the structural limitations that curtail their pedagogical agency. Addressing these constraints requires systemic support, curricular reimagination, and policy foresight so that learners are not only introduced to programming but are prepared to participate in the digital future.

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