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Teachers' Perceptions of Coding and Robotics Integration in Mpumalanga Province Schools

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ABSTRACT

Objective: This study aimed to examine the perceptions of teachers in Mpumalanga Province regarding the integration of coding and robotics into the science curriculum. The focus was on identifying existing attitudes, challenges, and the support required for effective implementation.

Methods: A mixed-methods research design was employed, involving both quantitative and qualitative approaches. Data were collected from 47 teachers across selected schools in the province. Quantitative data were gathered through structured questionnaires, while qualitative insights were obtained via semi-structured interviews. Descriptive statistics were used to analyze the quantitative data, and thematic analysis was applied to the qualitative responses.

Results: Findings revealed that teachers generally held positive attitudes towards integrating coding and robotics, recognizing their relevance in preparing learners for future careers. However, several significant challenges were identified, including inadequate infrastructure, limited teaching resources, insufficient training, and a lack of ongoing professional development. Additionally, some teachers reported cultural perceptions and misconceptions as barriers to effective implementation.

Conclusions: The study highlights the need for targeted, context-specific professional development programs and increased investment in school infrastructure to facilitate meaningful integration of coding and robotics into the science curriculum. Addressing cultural misconceptions through community engagement is also essential. Further research is recommended to inform policy and implementation strategies tailored to under-resourced educational contexts.

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Introduction

The South African education sector is undergoing a transformative shift with the introduction of Coding and Robotics education in schools. This initiative seeks to equip learners with the critical skills and knowledge necessary to participate meaningfully in the digital economy and contribute to the country's broader developmental objectives. However, the success of this curricular reform is contingent upon teachers' readiness and their perceptions of how effectively these subjects can be integrated into existing pedagogical practices, particularly in under-resourced and rural contexts.

To meaningfully integrate technology into teaching and learning, teachers require a sophisticated understanding of the dynamic interplay between technological, pedagogical, and content knowledge. The Technological Pedagogical Content Knowledge (TPACK) framework, developed by Mishra and Koehler (2007), provides a theoretical foundation for analysing this integration. TPACK emphasises the intersection of three core domains, technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK), and highlights that effective technology-enhanced teaching emerges from the ability to navigate and synthesise these forms of knowledge. Where this intersection is strong, teachers are more likely to deliver meaningful and contextually appropriate instruction; where it is weak, particularly in TK, pedagogical implementation may falter.

This study applies the TPACK framework to explore how teachers in Mpumalanga Province perceive and integrate Coding and Robotics into the science curriculum. By examining teachers' self-reported competencies, challenges, and support structures within each of the TPACK domains, the study seeks to identify areas requiring targeted professional development and resource allocation. This approach enables a comprehensive and context-sensitive understanding of the structural, pedagogical, and cognitive factors that shape technology adoption in educational settings.

In addition to TPACK, two further theoretical frameworks inform the analysis. First, Human Capital Theory provides a macro-level lens through which the national policy emphasis on Coding and Robotics can be understood. By investing in learners' digital skills, the curriculum reform aligns with broader goals of enhancing national competitiveness, economic productivity, and long-term employment prospects (Becker, 1964; Schultz, 1971). However, the theory also draws attention to the risks of uneven implementation, particularly when professional development and access to digital infrastructure are inequitably distributed across socio-economic and geographic contexts.

Second, the study draws on Constructivist Theory, which supports the pedagogical rationale for Coding and Robotics integration. Constructivism posits that learners construct knowledge through active, hands-on experiences that promote critical thinking, collaboration, and problem-solving (Piaget, 1950; Vygotsky, 1978). Robotics education, in particular, lends itself to constructivist pedagogies by engaging learners in iterative design, experimentation, and reflection, principles that are central to meaningful science learning (Papert, 1980). Together, these theoretical perspectives offer a multi-dimensional lens for examining the integration of emerging technologies in education. The study thus contributes to both localised understanding and broader academic discourse on the pedagogical, structural, and economic implications of STEM curriculum reform in developing contexts.

The integration of Coding and Robotics into the curriculum introduces a range of complex and interrelated challenges, particularly in under-resourced and rural contexts such as Mpumalanga Province. A principal concern remains the lack of teacher preparedness and targeted training in these emerging subject areas (Boice et al., 2021; Hill, Kim & Yuan, 2019). Many teachers enter the profession without prior exposure to coding and robotics during their initial teacher education programmes, resulting in limited content knowledge and pedagogical confidence (Giannandrea, Gratani & Renieri, 2021). Although early studies (e.g., Jacobsen, Clifford & Friesen, 2002) identified teacher uncertainty as a barrier to technological integration, more recent investigations (Montero-Mesa et al., 2023) demonstrate that without sustained professional development, teachers continue to experience anxiety and reluctance when implementing digital technologies in the classroom, particularly in resource-constrained environments.

Resource availability and infrastructural support also remain significant impediments to the effective delivery of Coding and Robotics education. In rural provinces such as Mpumalanga, schools frequently lack access to basic digital infrastructure, including computers, stable internet connections, and programmable robotics kits (Mpumalanga Department of Education [MDOE], 2022; Department of Basic Education [DBE], 2022). These material limitations extend beyond logistics; they represent pedagogical constraints that hinder experiential learning, innovation, and the development of computational thinking skills (Tshidi & Dewa, 2024). In such settings, teachers may be compelled to rely on theoretical instruction, which undermines the practical and exploratory nature of these subjects.

Moreover, cultural perceptions and gender stereotypes significantly shape both teacher practices and learner participation in STEM education. In many South African communities, entrenched gender norms continue to associate technical and scientific domains with masculinity, often marginalising female learners and limiting their participation in Coding and Robotics (Harmse & Dichaba, 2025). Teachers' own cultural assumptions may influence the extent to which they perceive these subjects as relevant or appropriate for all learners (Teise & Alexander, 2017). In rural areas, where traditional norms may be more pervasive and exposure to diverse role models is limited, these attitudes are likely to be more deeply ingrained (Ntsanwisi, 2024). Consequently, gender biases and cultural expectations not only shape classroom dynamics but may also influence the prioritisation and framing of Coding and Robotics content in the curriculum.

While there is increasing global scholarship on STEM education, studies that address Coding and Robotics within the South African context, particularly in rural areas, remain limited. Existing research has primarily focused on urban or relatively well-resourced environments (Boz & Allexsaht-Snider, 2022; Mapheto, 2023; Hart, 2023), thus neglecting the lived realities of teachers operating under systemic constraints. This gap is particularly problematic given the South African government's commitment to integrating these subjects nationally, regardless of provincial disparities.

Despite growing international interest in the integration of Coding and Robotics in school curricula, empirical research within the South African context remains limited, particularly in relation to rural and under-resourced settings. Existing studies (e.g., Tshidi & Dewa, 2024; Mapheto, 2023; Hart, 2023) have largely focused on urban or better-resourced environments, where access to technology, infrastructure, and teacher support systems is comparatively well-established. These studies offer valuable insights into curriculum implementation and teacher attitudes but do not fully capture the structural and socio-cultural constraints that define educational practice in rural areas.

Furthermore, while policy directives from the Department of Basic Education (Department of Basic Education [DBE], 2022) have outlined national ambitions for Coding and Robotics integration, there is a dearth of research that critically examines how these reforms are experienced by teachers in disadvantaged areas. The few existing rural-focused studies tend to concentrate on general ICT integration rather than the specific pedagogical demands of Coding and Robotics education (Mtshali, & Moses, 2024). As such, the current study addresses a significant gap by providing empirical data on how teachers in Mpumalanga perceive and navigate the challenges of implementing these curriculum reforms in their unique context.

Mpumalanga Province offers a particularly instructive case due to its combination of high rurality, infrastructural limitations, and persistent socio-economic disparities. These conditions present a markedly different implementation context from provinces such as Gauteng or the Western Cape. By concentrating on Mpumalanga, this study foregrounds the intersection of teacher preparedness, resource scarcity, and culturally embedded attitudes towards technology and gender, all of which critically shape educational outcomes but remain under-theorised in the existing literature.

The research is guided by the following question: What are the perceptions of teachers in Mpumalanga Province schools regarding the integration of Coding and Robotics education, including their preparedness, challenges, and recommendations?

Through this inquiry, the study contributes to the broader discourse on STEM education in developing contexts by generating context-specific insights that can inform professional development, curriculum planning, and infrastructure investment. By highlighting the lived experiences of teachers in Mpumalanga, the study offers a detailed understanding of how national reforms are mediated by local conditions, thereby enhancing the relevance of its findings for similar under-resourced contexts across South Africa and other low- and middle-income countries.

Material and Methods

This study adopted a convergent parallel mixed-methods research design to explore teachers' preparedness and perceptions regarding the integration of Coding and Robotics in schools. Mixed-methods research, as noted by Shorten and Smith (2017), enables a comprehensive understanding of educational phenomena by combining the strengths of quantitative and qualitative approaches. In this design, both types of data were collected concurrently, analysed separately, and then integrated during the interpretation phase to ensure triangulation and complementarity. Quantitative data provided descriptive and generalisable insights into trends in teacher preparedness, while qualitative data offered contextualised understandings of teachers' experiences and perspectives. The rationale for adopting the convergent parallel design, rather than a sequential design, lies in its ability to provide immediate, corroborative evidence on a complex issue during a single phase of data collection, enhancing the interpretive validity of the findings (Creswell & Plano Clark, 2018).

Purposive sampling was employed to select 47 teachers from Mpumalanga Province, with the sampling frame developed in consultation with the provincial Department of Basic Education. Participating schools were selected based on their involvement in the pilot implementation of the Coding and Robotics curriculum, representing both semi-urban and rural school settings. Selection criteria for participants included active involvement in teaching the new curriculum, a range of teaching experience (from novice to veteran), and subject specialisation across STEM and non-STEM disciplines. This purposive approach ensured that data were drawn from teachers with direct and relevant experience, thereby increasing the relevance and depth of the findings (Creswell, 2014).

A demographic summary of participants is presented in Table 1, including variables such as age, teaching experience, school location, and subject taught. These data are critical for interpreting the differential experiences and preparedness levels across diverse teacher profiles.

Table 1. Summary of Participant Demographics (n = 47)

Variable	Categories	Frequency	Percentage (%)
Gender	Male	23	48.9
	Female	24	51.1
School Location	Rural	25	53.2
	Semi-Urban	22	46.8
Teaching Experience	1–5 years	15	31.9
	6–10 years	19	40.4
	11–15 years	13	27.7
Subject Specialisation	Mathematics	8	17.0
	Science	10	21.3
	Technology	9	19.1
	Life Skills	8	17.0
	Natural Sciences	7	14.9
	English	5	10.6

The primary data collection instrument was a structured questionnaire administered electronically via Google Forms. The instrument consisted of both closed-ended and open-ended items. The closed-ended section was adapted from established instruments in STEM and educational technology research (e.g., Tondeur et al., 2017), and it was reviewed by two academic experts to establish content validity. A pilot study involving eight teachers outside the sample was conducted to assess reliability and clarity. The resulting Cronbach's alpha coefficient was 0.81, indicating acceptable internal consistency for the scale-based items.

The questionnaire covered four key domains:

1. Teacher perceptions of Coding and Robotics;
2. Professional development experiences;
3. Infrastructure and resource availability; and
4. Self-assessed content and pedagogical knowledge.

The qualitative component was embedded in the form of five open-ended questions designed to elicit in-depth responses about teachers' experiences, perceived barriers, and recommendations. Questions included prompts such as: "Describe your experience teaching Coding and Robotics," and "What challenges have you encountered, and how have you addressed them?"

Qualitative data were derived exclusively from the open-ended responses within the questionnaire. All qualitative responses were transcribed verbatim and subjected to thematic analysis following Braun and Clarke's (2006) six-phase framework. An inductive coding approach was adopted, allowing themes to emerge organically from the data without imposing preconceived categories. Manual coding was undertaken by the principal investigator, and codes were reviewed and refined to ensure analytical rigour and internal consistency. While software was not used for this stage due to the limited volume of text, consistency was maintained through iterative reading and peer debriefing with a colleague in qualitative research. Identified themes were then compared with the quantitative findings to ensure coherence and support the triangulation of results.

Quantitative data were analysed using descriptive statistical techniques, including frequencies, percentages, means, and standard deviations, to summarise teachers' responses across the four domains. Cross-tabulations were also used to explore patterns by demographic variables such as teaching experience and school location. The statistical analysis was conducted using Microsoft Excel and IBM SPSS (Version 27).

Ethical approval for the study was obtained from the University of South Africa's Research Ethics Review Committee. All participants received an information sheet explaining the aims of the study, the voluntary nature of participation, their right to withdraw at any stage without penalty, and the measures taken to ensure anonymity and confidentiality. Informed consent was obtained electronically prior to participation. All data were stored on password-protected devices and encrypted storage platforms, and were accessed only by the researcher. The study adhered strictly to the ethical principles of the Helsinki Declaration and institutional guidelines for research involving human subjects.

Results

This section presents the findings from both the quantitative and qualitative components of the study using a convergent parallel mixed-methods approach. Quantitative data, derived from structured questionnaires, are presented in summarised tables and supported by visual aids. Qualitative findings, extracted from open-ended responses, are reported thematically and illustrated with direct quotes. The findings are interpreted in light of the study's theoretical frameworks, namely TPACK, Human Capital Theory, and Constructivism—and relevant empirical literature.

Teachers expressed generally positive attitudes toward the integration of Robotics and Coding in education. As shown in Table 2, a majority agreed or strongly agreed that Robotics and Coding equip learners with future-ready skills. However, there was a notable proportion of neutral responses regarding their own preparedness, suggesting a gap between recognition of value and confidence in practice.

Table 2. Summary of Teacher Perceptions (n=47)

Statement	Agree/Strongly Agree (%)	Neutral (%)	Disagree/Strongly Disagree (%)
Robotics and coding prepare learners for the digital era	61.7%	38.3%	0%
I have sufficient knowledge of robotics and coding	55.3%	44.7%	0%
I received adequate training to teach Robotics and Coding	42.6%	10.6%	46.8%

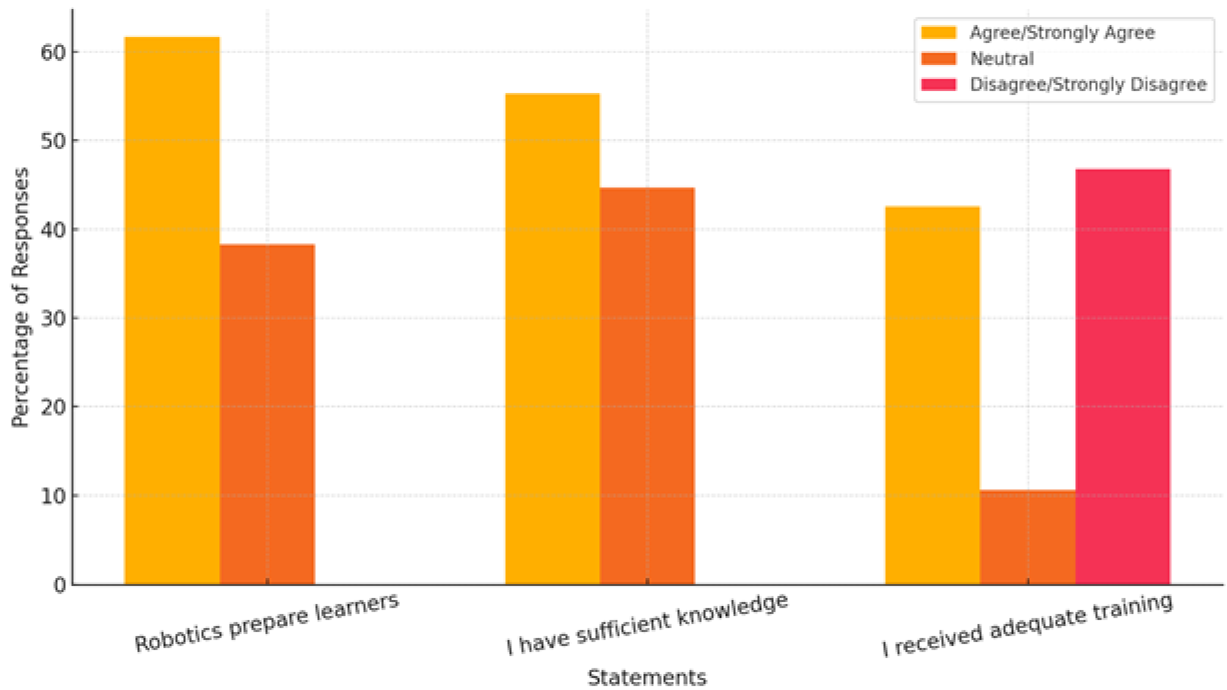

Figure 1: Teacher Perceptions of Robotics and Training Adequacy

Digital Technology Awareness and Competency Development

The responses to digital competency items (Table 3) demonstrate widespread engagement with core digital skills. Most teachers reported high levels of involvement in computational thinking, data management, coding techniques, and responsible use of technology. The items receiving the highest mean scores included:

- Explore data and information management skills (Mean = 4.3, SD = 0.8)
- Develop computational thinking and problem-solving skills (Mean = 4.3, SD = 0.7)
- Apply coding tools, techniques, and strategies (Mean = 4.3, SD = 0.7)

These findings indicate that respondents were confident and consistent in their implementation of key digital competencies. However, certain aspects such as "awareness of human-technology interaction" and "responsible use of digital technology" received slightly lower mean scores (Mean = 3.9) and higher standard deviations (SD = 1.0), suggesting some variability in responses and possible inconsistencies in pedagogical emphasis across schools.

The standard deviations suggest overall agreement but point to gaps in more complex areas of digital pedagogy, such as digital ethics. This supports the argument that while technological and content knowledge (TK and CK) are present, pedagogical integration (TPK) remains underdeveloped in specific areas, echoing findings in the TPACK framework.

The implications are clear: to achieve balanced digital literacy, professional development efforts should not only focus on technical capabilities but also include structured guidance on ethical and social considerations of digital tool use. This reinforces findings from Barker and Ansorge (2007), who noted that deeper engagement with robotics and digital tools fosters not only cognitive but also affective and social learning outcomes. Similarly, Freeman et al. (2014) argue that such integration promotes critical thinking and collaborative skills, which were indirectly evidenced by high engagement in computational activities.

Table 3. Digital Competency Development: Descriptive Statistics Summary

Question	Never	Almost never	Sometimes	Mostly	Always	Mean	Standard Deviation
Explore digital skills and competency	0.0	0.0	15.0	19.0	13.0	3.96	0.77
Explore basic graphic and visual representation	0.0	0.0	10.0	16.0	21.0	4.23	0.78
Use digital technology responsibly	0.0	0.0	15.0	19.0	13.0	3.96	0.77
Explore data and information management skills	0.0	0.0	9.0	15.0	23.0	4.3	0.77
Develop computational thinking & problem-solving skills	0.0	0.0	7.0	18.0	22.0	4.32	0.72
Explore algorithms and code (stories/games)	0.0	0.0	14.0	17.0	16.0	4.04	0.8
Build digital skills and competency	0.0	0.0	15.0	18.0	14.0	3.98	0.79
Graphic and visual design/representation	0.0	0.0	17.0	15.0	14.0	3.93	0.82
Awareness of human-technology interaction	2.0	1.0	5.0	19.0	20.0	4.15	0.99
Responsible digital technology use	2.0	1.0	6.0	18.0	20.0	4.13	1.0
Further develop problem-solving skills	0.0	0.0	7.0	20.0	20.0	4.28	0.71
Use coding to solve basic problems	0.0	1.0	5.0	13.0	20.0	4.33	0.8
Think computationally	0.0	1.0	6.0	15.0	20.0	4.29	0.8
Apply coding tools and strategies	0.0	1.0	5.0	13.0	20.0	4.33	0.8

Figure 2 visually depict this positive trend and highlight the areas where support and pedagogical refinement are needed.

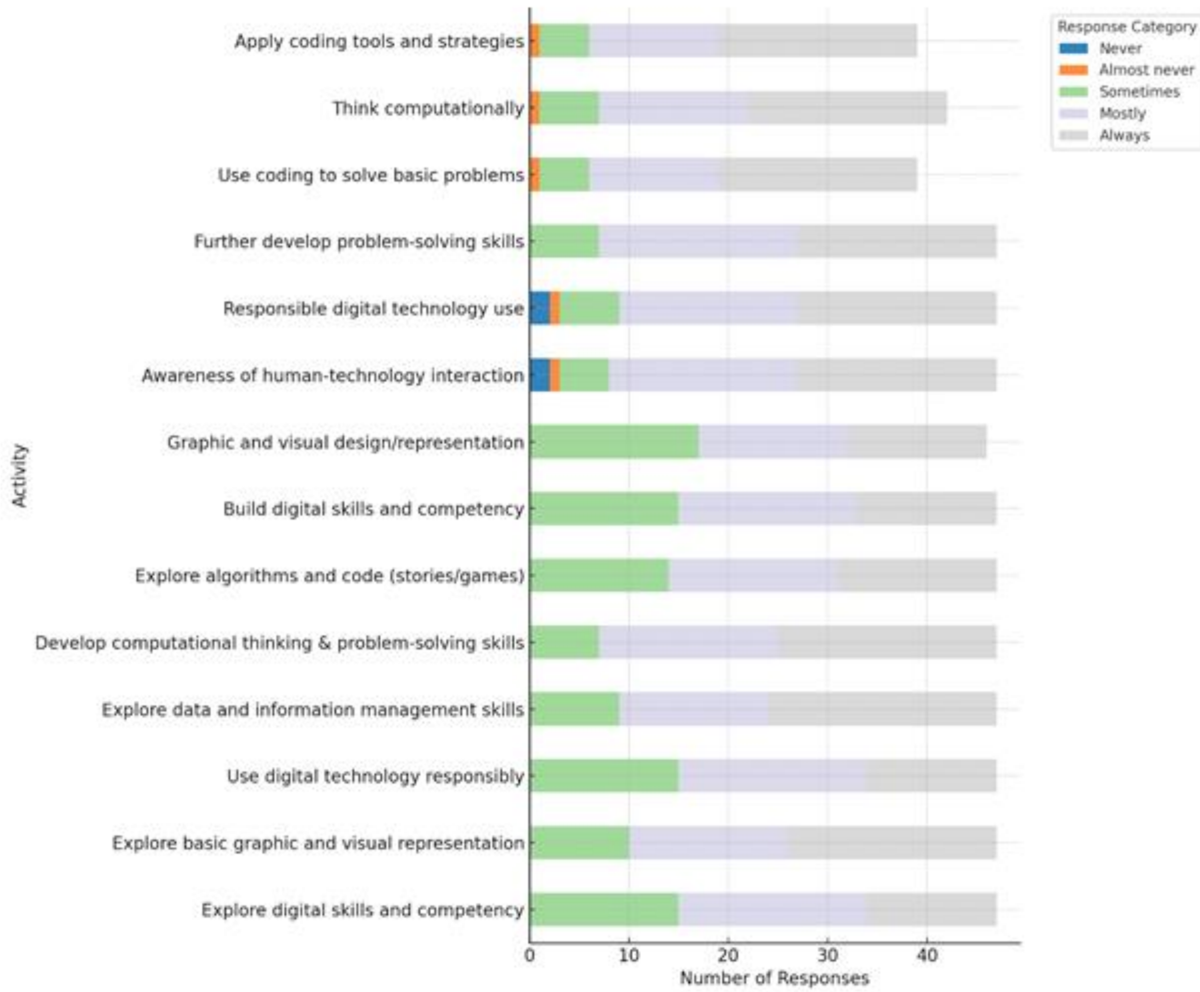

Figure 2: Teachers' Responses on Digital Competency Development Activities

Digital Competency and Pedagogical Integration

Table 4 summarises teachers' responses related to digital technology awareness. Most respondents reported frequent engagement with digital skill development and the ethical use of technology. Notably, computational thinking and coding as problem-solving tools were rated highly.

Table 4. Teachers' Engagement in Digital Competency Development

Skill Area	Mostly/Always (%)
Problem-solving and computational thinking	85.1%
Responsible technology use	80.8%
Basic graphic and visual representation	78.7%

These results suggest an emerging culture of digital integration, though gaps in training (Table 1) indicate that formal support mechanisms remain inconsistent.

Thematic analysis yielded six major themes: (1) Perceptions and Attitudes; (2) Professional Development; (3) Challenges and Resource Constraints; (4) Learner Engagement and Outcomes; (5) Implementation Strategies; and (6) Recommendations for Support.

Perceptions and Attitudes

Most teachers expressed enthusiasm for Robotics and Coding, describing them as "essential for 21st-century skills" and "aligned with what learners enjoy doing." One respondent noted:

"When learners build and code robots, they become more involved than in traditional classes."

This enthusiasm may reflect recent curriculum mandates and broader national emphasis on digital transformation, aligning with Human Capital Theory's emphasis on preparing learners for future economic participation (Becker, 1964).

Professional Development

Despite positive attitudes, most teachers cited inadequate training:

"I was given materials but no practical training, it's difficult to teach what you haven't done yourself."

This finding illustrates the gap in Technological Pedagogical Content Knowledge (TPACK). Teachers with insufficient TPK and TCK struggled to translate robotics content into effective pedagogy. Without targeted, ongoing CPD, the TPACK framework remains underdeveloped.

Challenges and Resource Constraints

Although the original survey did not explicitly ask about barriers, qualitative responses revealed indirect evidence of systemic challenges:

"We only have one computer lab for the whole school, it's booked all the time." "Sometimes I have ideas, but there are no kits to use."

This suggests that while respondents may not have explicitly labelled these as 'challenges', infrastructural deficits and material constraints were pervasive. This aligns with Kozma's (1994) theory of technological determinism, where technology availability dictates pedagogical possibilities.

Learner Engagement and Learning Outcomes

Teachers reported increased learner motivation, citing improved collaboration and problem-solving skills:

"Even my quiet learners became active when we introduced coding tasks."

This is consistent with Constructivist learning theory (Vygotsky, 1978), emphasising the importance of hands-on, socially mediated experiences. Learners appeared to benefit cognitively and affectively from the active learning environments fostered by robotics.

Implementation Strategies

Teachers adopted varied strategies such as project-based learning, group work, and real-world scenarios. One teacher explained:

"I give learners a challenge, like programming a robot to follow a line—they solve it in teams."

Such strategies reflect both best practices in STEM education and alignment with inquiry-based pedagogies.

Recommendations for Professional Development

Findings suggest that effective PD must go beyond one-off workshops. Teachers called for:

- Hands-on training with robotics kits;
- Peer-learning communities to share resources and troubleshoot;
- Curriculum-aligned content integrating robotics with CAPS.

Addressing resource inequality requires practical policy interventions—such as district-provided mobile robotics labs, investment in teacher mentorship programmes, and inclusion of robotics training in pre-service curricula.

Integration of Findings and Theoretical Frameworks

This study confirms the relevance of TPACK in Robotics and Coding education. Where all three knowledge domains (content, pedagogy, and technology) intersect, teachers felt most confident and effective. Conversely, where technological knowledge was lacking, pedagogical implementation suffered. Human Capital Theory contextualises the policy emphasis on coding as a means to boost national competitiveness. However, unless professional development and resource access are equitably distributed, the benefits may not be uniformly realised. Constructivist theory supports the shift from traditional rote methods to learner-centred robotics integration, with evidence of increased engagement, collaboration, and deep learning.

Discussion

The positive attitudes towards coding and robotics can be contextualized within the framework of Human Capital Theory (Becker, 1964), which posits that investments in education enhance individual productivity and economic outcomes. Teachers perceive these subjects as vital for equipping learners with skills relevant to the modern workforce, reflecting an understanding of education as a means to improve future employability.

Despite acknowledging the importance of coding and robotics, many teachers reported insufficient training, highlighting a gap in the integration of Technological Pedagogical Content Knowledge (TPACK) (Mishra & Koehler, 2006). While teachers possess content knowledge and are developing pedagogical strategies, the lack of technological proficiency hinders effective implementation. This imbalance suggests a need for professional development programs that holistically address all components of TPACK.

The adoption of hands-on, project-based learning aligns with Constructivist theories (Vygotsky, 1978; Piaget, 1950), which advocate for learner-centred approaches that promote active engagement and knowledge construction. Teachers' use of real-world analogies and collaborative projects facilitates deeper understanding and retention of concepts among learners. The reported challenges, including inadequate infrastructure and limited resources, are consistent with barriers identified in existing literature (Ertmer & Ottenbreit-Leftwich, 2010; Liu et al., 2019). These obstacles underscore the necessity for systemic support, encompassing not only teacher training but also the provision of necessary technological tools and infrastructure.

In response to the study's findings, several tailored recommendations are proposed to enhance teacher preparedness and support the effective integration of Coding and Robotics education. Firstly, professional development should include modular, practical training sessions that are explicitly aligned with the domains of the TPACK framework, ensuring that teachers develop balanced competencies in technology, pedagogy, and content. Mentorship and coaching programmes should be established to facilitate knowledge sharing between novice and experienced teachers in the field of robotics. To further support instructional practice, open-access repositories containing lesson plans, instructional videos, and peer-reviewed teaching resources should be developed and maintained. The integration of coding and robotics should not be limited to in-service training but must be embedded within initial teacher education programmes to ensure early and systematic exposure. Given the geographic and infrastructural disparities in the region, the implementation of online and blended learning platforms is essential to provide ongoing, accessible professional development opportunities, particularly for teachers in remote and under-resourced contexts.

The challenges identified in this study, such as inadequate infrastructure and limited resources, align with barriers commonly reported in the literature (Ertmer & Ottenbreit-Leftwich, 2010; Liu et al., 2019). These obstacles underscore the necessity for systemic support, encompassing not only teacher training but also the provision of necessary technological tools and infrastructure. Addressing these challenges requires a multifaceted approach that includes policy development, curriculum enhancement, and efforts to bridge the digital divide.

The findings of this study have several implications for policy and curriculum design. Educational authorities should formulate policies that mandate comprehensive professional development programs, ensuring that teachers are equipped with the requisite skills to integrate technology effectively. Such policies would support teachers in overcoming barriers to technology integration and enhance their capacity to deliver effective instruction.

Curricula should be revised to incorporate coding and robotics from early education levels, fostering digital literacy from a young age. Integrating these subjects into the curriculum can prepare learners for future careers and equip them with essential skills for the digital era. Efforts must be made to bridge the digital divide, ensuring that all schools, regardless of location or socioeconomic status, have access to the necessary resources and support. This includes providing adequate infrastructure, technological tools, and ongoing support to facilitate the effective integration of technology in education.

Conclusion

This study investigated the perceptions of teachers in Mpumalanga Province regarding the integration of coding and robotics education into their classrooms. The findings reveal a general positive attitude among teachers toward these subjects, recognizing their importance in equipping learners with skills relevant to the digital age. However, challenges such as insufficient training, limited resources, and infrastructural constraints were identified, underscoring the need for comprehensive professional development programs and systemic support.

A notable contribution of this research lies in its focus on a developing context, providing insights into the unique challenges and opportunities present in South African schools. The mixed-methods approach employed offers a comprehensive understanding of teachers' experiences, combining quantitative data with qualitative insights to inform practical recommendations.

While the study offers valuable perspectives, certain limitations must be acknowledged. The sample size was relatively small and may not fully represent the diverse experiences of all teachers in the province. Additionally, reliance on self-reported data introduces the possibility of response bias, and the absence of student perspectives limits the comprehensiveness of the findings. Future research should consider larger, more diverse samples and incorporate multiple stakeholder viewpoints to enhance the generalizability and depth of understanding in this field.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving human participants were reviewed and approved by the ethics committee of University of South Africa. The patients/participants provided their written informed consent to participate in this study.

Author contributions

T. Mhlongo contributed to the study conception and design, material preparation, data collection, and analysis. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

References

Barker, B. S., & Ansorge, J. (2007). Robotics as means to increase achievement scores in an informal learning environment. *Journal of Research on Technology in Education, 39*(3), 229–243. https://doi.org/10.1080/15391523.2007.10782481

Becker, G. S. (1964). *Human capital: a theoretical and empirical analysis, with special reference to education* (Vol. 3). Chicago: University of Chicago Press.

Becker, G. S. (1964). *Human capital: a theoretical and empirical analysis, with special reference to education* (Vol. 3). Chicago: University of Chicago Press.

Boice, K. L., Jackson, J. R., Alemdar, M., Rao, A. E., Grossman, S., & Usselman, M. (2021). Supporting Teachers on Their STEAM Journey: A Collaborative STEAM Teacher Training Program. *Education Sciences, 11*(3), 105. https://doi.org/10.3390/educsci11030105

Boz, T., Allexsaht-Snider, M. How do elementary school teachers learn coding and robotics? A case study of mediations and conflicts. *Educ Inf Technol* 27, 3935–3963 (2022). https://doi.org/10.1007/s10639-021-10736-4

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Creswell, J. W. (2021). *A concise introduction to mixed methods research*. SAGE publications.

Creswell, J. W., & Plano Clark, V. L. (2023). Revisiting mixed methods research designs twenty years later. *Handbook of mixed methods research designs*, *1*(1), 21-36.

Department of Basic Education. (2022, November 22). *DBE and Vodacom visit Mpumalanga schools piloting the Coding and Robotics curriculum*. https://www.education.gov.za/ArchivedDocuments/ArchivedArticles/Mpumalanga-Coding-and-Robotics-curriculum-1122.aspx

Ertmer, P. A., & Ottenbreit-Leftwich, A. T. (2010). Teacher technology change: How knowledge, confidence, beliefs, and culture intersect. *Journal of Research on Technology in Education*, *42*(3), 255–284. https://doi.org/10.1080/15391523.2010.10782551

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, *111*(23), 8410–8415. https://doi.org/10.1073/pnas.1319030111

Giannandrea, Lorella, et al. "Crossing boundaries: documentation of a teacher training course on design, robotics and coding" Research on Education and Media, vol. 12, no. 1, Sciendo, 2020, pp. 85-92. https://doi.org/10.2478/rem-2020-0010

Harmse, L., & Dichaba, M. (2025). Investigating the Factors Contributing to the Underrepresentation of Female Lecturers in STEM Disciplines at a TVET College. *Journal of Culture and Values in Education*, *8*(1), 70-85. https://doi.org/10.46303/jcve.2025.5

Hart, S. A. (2023). Identifying the factors impacting the uptake of educational technology in South African schools: A systematic review. *South African Journal of Education*, *43*(1), 1–16. https://doi.org/10.15700/saje.v43n1a2174

Hill, R. B., Kim, C. M., & Yuan, J. (2019). Robotics and coding in primary grades. In M. Tsitouridou, T. A. Mikropoulos, & J. A. Diniz (Eds.), *Technology and Innovation in Learning, Teaching and Education - 1st International Conference, TECH-EDU 2018, Revised Selected Papers* (pp. 458-467). (Communications in Computer and Information Science; Vol. 993). Springer Verlag. https://doi.org/10.1007/978-3-030-20954-4_34

Jacobsen, M., Clifford, P., & Friesen, S. (2002). Preparing teachers for technology integration: Creating a culture of inquiry in the context of use. *Contemporary issues in technology and teacher education*, *2*(3), 363-388.

Kozma, R.B (1994). *Will* media influence learning? Reframing the debate. *ETR&D* 42, 7–19. https://doi.org/10.1007/BF02299087

Liu, S. H., Lin, C. S., & Zhang, D. (2019). Pedagogical beliefs and attitudes toward information and communication technology: A survey of teachers of English as a foreign language in China. *Computer Assisted Language Learning*, *32*(8), 858–880. https://doi.org/10.1080/09588221.2018.1531033

Mapheto, D. (2023). *Teachers' And Learners' Acceptance of the use of Robotics in the Intermediate Phase* (Master's thesis, University of Pretoria (South Africa)). DOI: 10.25403/UPresearchdata.25117697

Mishra, P., & Koehler, M. J. (2007, March). Technological pedagogical content knowledge (TPCK): Confronting the wicked problems of teaching with technology. In *Society for Information Technology & Teacher Education International Conference* (pp. 2214-2226). Association for the Advancement of Computing in Education (AACE).

Mnisi, B. R., Mtshali, T. I. ., & Moses, M. . (2024). Moving beyond the challenges of learning through technologies: The current status of ICT integration in South African schools. *Journal of Education and E-Learning Research*, *11*(1), 128–134. https://doi.org/10.20448/jeelr.v11i1.5396

Montero-Mesa, L., Fraga-Varela, F., Vila-Couñago, E., & Rodríguez-Groba, A. (2023). Digital Technology and Teacher Professional Development: Challenges and Contradictions in Compulsory Education. *Education Sciences*, *13*(10), 1029. https://doi.org/10.3390/educsci13101029

Mpumalanga Department of Education. (2022). *Annual report 2021/22 financial year*. Mpumalanga Provincial Government. https://www.mpg.gov.za/sites/default/files/resources/21_22%20AR.pdf

Ntsanwisi, S. (2024). Bridging Gaps in STEM Education: The Case for Dedicated Learning Centres in South African Townships and Rural Areas. *European Journal of STEM Education, 9*(1), 15. https://doi.org/10.20897/ejsteme/15481

Papert, S. (1980). Mindstorms: Children, computers, and powerful ideas. Basic Books.

Piget, J. (1950). The psychology of intelligence. Routledge & Kegan Paul.

Schultz, T. W. (1971). Investment in human capital. The role of education and of research.

Shorten, A., & Smith, J. (2017). Mixed methods research: expanding the evidence base. *Evidence-based nursing*, *20*(3), 74-75.https://doi.org/10.1136/eb-2017-102699

Teise, K. L., & Alexander, G. (2017). Perceptions of teacher education students at a South African university on the relationship between culture and education: Implications for social justice. *Koers – Bulletin for Christian Scholarship,* *82*(3), 1–10. https://doi.org/10.19108/KOERS.82.3.2334

Tondeur, J., Aesaert, K., Prestridge, S., & Consuegra, E. (2017). A multilevel analysis of what matters in the training of pre-service teacher's ICT competencies. *Computers & Education, 122*, 32–42. https://doi.org/10.1016/j.compedu.2018.03.002

Tshidi, M., & Dewa, A. (2024). 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*, *96*, 140–160. http://dx.doi.org/10.17159/2520-9868/i96a08

Tshidi, M., & Dewa, T. (2024). *The digital divide and curriculum implementation in South African schools: A scoping review of Coding and Robotics education*. Journal of Educational Development, 96, 1–21. https://scielo.org.za/pdf/jed/n96/09.pdf

Vygotsky, L. S. (1978). Mind in society: The development of higher psychological processes. Harvard University Press.