https://doi.org/10.64211/oidaijsd190616

Exploring Electrical Technology Teachers' Enactment of TPACK in The Teaching of Programmable Logic Controllers (PLCs)

Nzaliseko Dayi [1,*], Thokozani Isaac Mtshali [2], Ramongwane Daniel Sephokgole [3]
[1,2,3] Department of Technology and Vocational Education, Tshwane University of Technology, South Africa.
[*] Corresponding author: dayiisaacnzaliseko@gmail.com

© Authour (s)
OIDA International Journal of Sustainable Development, Ontario International Development Agency, Canada.
ISSN 1923-6654 (print) ISSN 1923-6662 (online) www.oidaijsd.com
Also available at https://www.ssrn.com/index.cfm/en/oida-intl-journal-sustainable-dev/

Abstract: This study explored Electrical Technology teachers' enactment of Technological Pedagogical Content Knowledge (TPACK) in the teaching of Programmable Logic Controllers (PLCs). Anchored in a qualitative research approach, a case study design was employed to gain rich, contextual insights into classroom practices. The research focused on a population of ten technical high schools offering Electrical Technology (Power Systems) in the Gauteng province, South Africa. A purposive sample of six (6) teachers was selected based on their experience and involvement in teaching Programmable Logic Controllers (PLCs). The data was collected through non-participant classroom observations to capture authentic teaching interactions without interference. Thematic analysis was used to interpret the qualitative data that was primarily described based on what was observed in the classroom, highlighting patterns in how teachers integrate technology with pedagogy and content knowledge. Preliminary findings indicate that, while teachers display fundamental TPACK understanding, its implementation is frequently dependent on available technological resources, confidence in using PLC tools for simulation and curricular alignment. The study anticipates that professional development centred on practical technology integration and TPACK upgrading will be critical in promoting more successful Programmable Logic Controllers' learning. These findings contribute to the wider discussion of integrating Industry 4.0 technology into technical and Vocational Education (VOC).

Keywords: Electrical Technology, PLCs, teacher knowledge, TPCK, Vocational Education.

Introduction

In recent years, there has been a global movement in how technology is integrated into the classroom, particularly in technical and vocational education. This transition is largely driven by the rapid introduction of Industry 4.0 technologies such as automation, robotics and programmable logic controllers (PLCs) [1]. PLCs are becoming an essential component in many industrial systems, so technical schools offering Electrical Technology (Power systems) must provide learners with applicable skills and knowledge for this developing landscape. However, teaching PLCs effectively involves more than just technical knowledge, it requires a thorough understanding of how to integrate content knowledge with proper pedagogy and digital tools [2]. This intersection is captured in the Technological Pedagogical Content Knowledge (TPACK) framework, developed by Mishra and Koehler [3], which affirms that effective teaching with technology requires the thoughtful integration of technology, pedagogy and content.

Electrical Technology teachers in technical schools are frequently required to teach complex concepts such as programming languages, Variable Speed Drives (VFDs) among others with limited resources and strict curriculum limitations. Furthermore, many teachers may lack professional training in the use of new digital tools into their classroom methods. As recent studies points out, simply having access to technology is insufficient; teachers must also understand how to meaningfully integrate it into their classes [4]. Furthermore, Koehler and Mishra (2009) emphasize that effective technology integration should be embedded in teachers' understanding of both the subject matter and the teaching methods appropriate for unique learners. Likewise, recent literature reveals that without a deep understanding of TPACK, teachers may struggle to bridge the gap between technology and instruction, especially in technical subjects like Electrical Technology [5].

In the South African context, the Department of Basic Education implemented PLCs into the Electrical Technology (Power Systems) subject curriculum, specifically for learners in the Further Education and Training (FET) phase [6]. Resultantly, this topic has turned into be a monster among other topics or chapters like Three-Phase AC generation, Motors and starters and Resistor Inductor Capacitor circuits (RLC circuits). However, there is still a not much research done into how teachers really use TPACK when teaching this topic of Programmable Logic Controllers (PLCs). Most existing TPACK research has been on general education or areas such as mathematics and science. Few studies have explored how vocational teachers, particularly those teaching Electrical Technology (Power systems), implement TPACK ideas in their daily classroom practice. This points to a critical knowledge gap in the literature.

Furthermore, teaching PLCs is not just a theoretical exercise. It frequently necessitates hands-on experience with real or virtual industrial instruments, creating extra challenges for schools with limited resources and infrastructure. As most recent literature highlights, the digital gap remains a significant barrier in many South African technical schools, particularly in technical and vocational subjects [7]. This means that the effectiveness of technology integration may be dependent on more than just legislative regulations. It also requires an understanding of how teachers interpret and apply their knowledge in real-world classroom contexts. As a result, examining how teachers effectively implement their TPACK in PLCs is not only important, but also necessary for the betterment of learners' results.

Given these issues, our research is both urgent and important. It is primarily concerned with how Electrical Technology (Power systems) teachers in Gauteng Province, South Africa teach PLCs using their technological, pedagogical and subject expertise. By investigating this technique in real classrooms through non-participant observations, the study hopes to gain a better understanding of the strengths, gaps and opportunities in present teaching methods. The findings can help with teacher training, curriculum development and resource planning. Finally, this study fills a vital knowledge gap by offering light on the implementation of TPACK in teaching PLCs which is an area of concern that is underexplored in South Africa.

Role of TPACK in teaching technical subjects

The integration of technology into teaching is no longer optional, especially in technical areas such as Electrical Technology, where curriculum is strongly related to present industrial practices. The TPACK framework, first presented by Mishra and Koehler, emphasizes that effective technology-based education takes more than just knowing how to use tools [8]. But, it also requires an evolving awareness of how content, pedagogy and technology interrelate. TPACK is particularly helpful in disciplines that are both practical and content-heavy, such as teaching Programmable Logic Controllers (PLCs).

PLCs are the foundation of automated systems used in manufacturing, electricity generation and process control. As a result, teaching this topic requires a balanced approach that combines theory and practical application. According to current research, TPACK allows teachers to make more informed decisions about how and when to use technology to improve the educational experience for learners [9]. This means that Electrical Technology teachers who understand TPACK are better positioned to teach complicated topics like PLCs in meaningful and industry-appropriate ways.

However, many technical teachers are typically trained mostly on content knowledge and have had little formal experience to pedagogical and technological integration. As current studies hilifghts, without a good pedagogical basis, even the most advanced technologies can fail to improve the outcomes of learning [10]. This implies that the function of TPACK in technical education is not only theoretical, but also critical to the success of classroom instruction. Furthermore, other studies emphasize that the building of TPACK is an ongoing process that includes reflective practice, contextual awareness and professional development [11].

Despite this, there is still a lack of empirical research on how TPACK is used in technical and vocational topics in South African schools. Most TPACK research has focused on general education contexts. This creates an unfilled space in understanding how teachers of subjects such as Electrical Technology use or struggle to use TPACK in their daily instructional activities. By filling this gap, the current study not only advances theory but also promotes better informed teacher teaching strategies in the Technical and Vocational Education and Training (TVET) and vocational institutions of learning.

Challenges and Opportunities in Teaching PLCs In South African Technical Schools

Teaching PLCs in technical schools offers major challenges and opportunities, particularly in South Africa. On the other side, the inclusion of PLCs to the Electrical Technology curriculum represents a gradual movement toward aligning school-based learning with industrial standards. In contradiction, many schools lack the resources, infrastructure and teacher support required to properly provide this curriculum. Current research reveals state that the digital divide in South African education continues to hinder the use of technology in many classrooms, particularly in township and rural schools [12].

One of the primary issues is a lack of functional PLC gear and licensed software in schools. This reduces learners' exposure to the practical aspects of PLC hands-on learning, making it difficult to achieve the desired learning results. Also, teachers are frequently required to teach complicated digital systems despite having received inadequate training themselves. This leads to a reliance on theoretical explanations and textbook information, which goes against the hands-on character of technical vocational subjects or content. As literature advocates, preparing learners with Industry 4.0 skills involves investments not only in infrastructure but also in teacher training and curriculum change [13].

Yet, this problem might also provide an opportunity. With the development of simulation-based tools and open-source PLC software, schools can now use digital alternatives that simulate real-world PLC programming environments. According to recent studies, such tools are increasingly being employed around the world to bridge the gap between classroom education and workplace practice [14]. Likewise, another study suggest that simulation platforms can improve learners' problem-solving skills, save equipment costs and enable teachers to experiment with innovative teaching methods [15].

Nonetheless, successful integration of such tools is dependent on the teacher's ability to properly integrate technology with pedagogy and content. This highlights the importance of the TPACK framework as a roadmap for enhancing teaching practice in resource-constrained settings. The current study addresses this demand directly by studying and observing how Electrical Technology teachers are currently using TPACK to teach PLCs. The findings will provide practical insights for future teacher training programs, resource allocation and curricular support systems. This work addresses a major gap in the literature while also contributing to efforts to improve technical education results in South Africa.

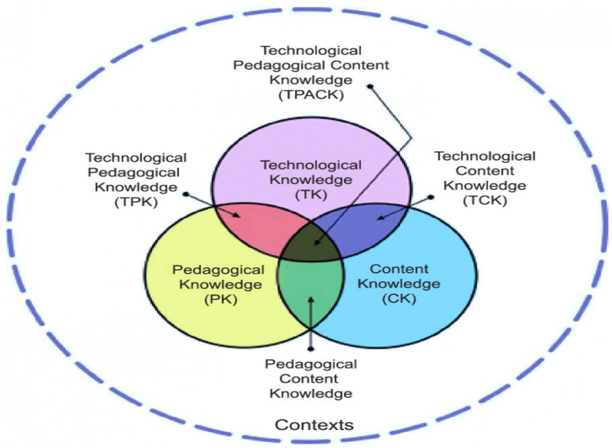
Theoretical Framework

This study used the Technological Pedagogical Content Knowledge (TPACK) model as a theoretical framework to understand how Electrical Technology teachers integrate digital tools into their teaching of Programmable Logic Controllers (PLCs). The TPACK model, created by Mishra and Koehler [3, 16] provides a structured approach to examining the types of knowledge teachers require to effectively teach with technology. It focuses on the intersection of three primary forms of teacher knowledge: content knowledge (CK), pedagogical knowledge (PK) and technological knowledge (TK). When these knowledge areas are meaningfully combined, they form an integrated framework that assists teachers in making informed decisions.

This framework emphasizes that simply understanding how to navigate technology is insufficient, so teachers must also understand how to use it in ways that support their subject knowledge and proper teaching practices. In this study, TPACK is especially important since teaching PLCs needs a combination of theoretical knowledge, hands-on demonstration and the use of specific digital tools and simulations. This makes the TPACK model a suitable lens for exploring how teachers integrate these knowledge areas in real-world Electrical Technology (Power systems) classroom settings. Figure 1 below shows a diagrammatic representation of TPCK model as it was used as the theoretical framework to underpin the study.

Next page

Figure 1: The TPCK framework



In this study, data collection and analysis were guided by the TPACK framework. Non-participant classroom observations focused on how teachers used technology resources, instructional tactics (demonstrations or guided practice) and subject matter expertise (input/output control logic). The framework also helped identify weaknesses or strengths in how teachers applied these types of knowledge during class delivery [3, 16]. Furthermore, the use of TPACK added greatly to the study by providing a thorough and practical framework for interpreting how technology is integrated in technical disciplines. It enabled a concentrated examination of teaching techniques in Electrical Technology, highlighting opportunities for professional development, curriculum support and policy consideration.

Methodology

The study used a qualitative research approach to provide rich, descriptive and insight into how Electrical Technology teachers use Technological Pedagogical Content Knowledge (TPCK) when teaching Programmable Logic Controllers (PLCs). This technique enabled for a more in-depth knowledge of the teachers' teaching practices, experiences and contextual realities, which were expressed in human-centred terms rather than numerically [17]. Also, the data that was collected through non-participant observations was analysed thematically. A case study research approach was used as a tool for investigating real-life events in their specific settings [18].

Participants.

This study's population included eleven technical high schools in South Africa's Gauteng province that offer Electrical Technology with a concentration on Power Systems. Six schools were chosen specifically from this group based on their active adoption of the PLC curriculum [19]. The study involved one teacher from each of the six selected technical schools, which adds up to a sample size of six (6) Electrical Technology teachers. These teachers were purposively selected for their experience and involvement in teaching PLC curriculum, making them a valuable source of information about the issue under inquiry.

The rationale behind using this sample size was to allow for in-depth, context-rich understanding of how Electrical Technology teachers enact TPACK when teaching PLCs. Six teachers were purposively selected from eleven technical schools in Gauteng, representing a significant portion of teachers offering the subject. These participants were directly involved in PLC instruction, making them information-rich cases. The use of non-participant observations required focused engagement in each classroom, which justified this smaller and manageable sample. Furthermore, data saturation was achieved as similar teaching patterns were consistently observed across the six technical schools, confirming that the sample was sufficient to draw meaningful conclusions within this context.

Instruments for data collection and procedures

The primary data collection approach used in the study was non-participant classroom observations. This strategy enabled the researcher to observe how teachers integrate technical, pedagogical and subject knowledge in real time, without influencing or changing the classroom environment [20]. The observations focused on how teachers used digital tools, arranged learning activities and communicated subject content during PLC lessons. A standardized observation procedure was employed to guide the process and maintain consistency across multiple school settings.

Ethical considerations/ procedures

Permission to conduct the study had been obtained from both the Gauteng Department of Education and the principals of the selected technical schools. All participating teachers received informed consent papers that fully explained the study's purpose and participants' rights. Participants were assured that their replies and names would be kept completely anonymous and used only for academic purposes. To maintain the privacy and confidentiality of participants, pseudonyms were employed in the data records and findings.

Procedures to mitigate internal biases of the collected data

To reduce bias in the collected data, some steps were followed during data collection and analysis. Non-participant classroom observation was used so that lessons could proceed naturally without interference from the researcher, allowing Electrical Technology teachers to present PLCs content using their usual teaching aids or tools such as PowerPoint slides, chalkboards and PLC trainers in their normal way. In addition, a structured observation guide was used across all six classrooms to ensure consistency, with greater attention paid to teacher and learner interaction, use of technological tools and delivery of content. This made it possible to capture patterns such as teacher-centred teaching and limited learner participation in a consistent manner. To reduce bias, sufficient time was spent in each lesson to observe repeated teaching practices rather than isolated incidents, such as the continued use of demonstrations without active learner involvement. During analysis, themes were developed from what was directly observed in the classrooms, ensuring that findings were grounded in actual practice. Visual data, including slides, diagrams and chalkboard summaries were interpreted together with teacher explanations to maintain accurate meaning. The teacher was also given a chance to verify the researchers' findings (member checking) which ensured that the researcher did not try to influence the data of findings towards certain prescribed conclusions. Furthermore, detailed observation notes were also kept throughout the study to ensure that conclusions were based on real classroom evidence but not on personal assumptions and interests.

Results and Discussion

As previously stated, the study used thematic analysis to interpret the qualitative data collected through non-participant observations. This approach assisted in identifying common trends in how Electrical Technology teachers integrated technology with pedagogy and content knowledge when teaching Programmable Logic Controllers (PLCs). Two significant themes emerged from the data, reflecting how teachers enacted their TPACK in the teaching of PLCs. It was discovered that Electrical Technology (Power systems) teachers use:

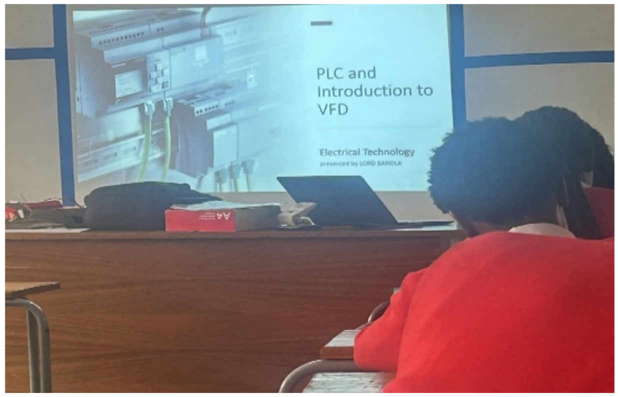
- PowerPoint presentation slides and a whiteboard or chalkboard to deliver content.
- Various teaching strategies aimed at supporting learners' understanding of PLC concepts.

Theme 1: The use of PowerPoint presentation slides and a whiteboard or chalkboard to deliver content.

Teacher A began the lesson with a series of PowerPoint slides that listed and shown PLC input and output devices. Each slide had clear labels and definitions and the teacher read through them, sometimes pointing to visuals. Following the PowerPoint presentation, the teacher used the whiteboard to create a simplified illustration of how a pushbutton operates an actuator through a PLC. Figure 2 below shows how the Electrical Technology teacher delivered his lesson.

Next Page

Figure 2: Teacher A's PowerPoint slide

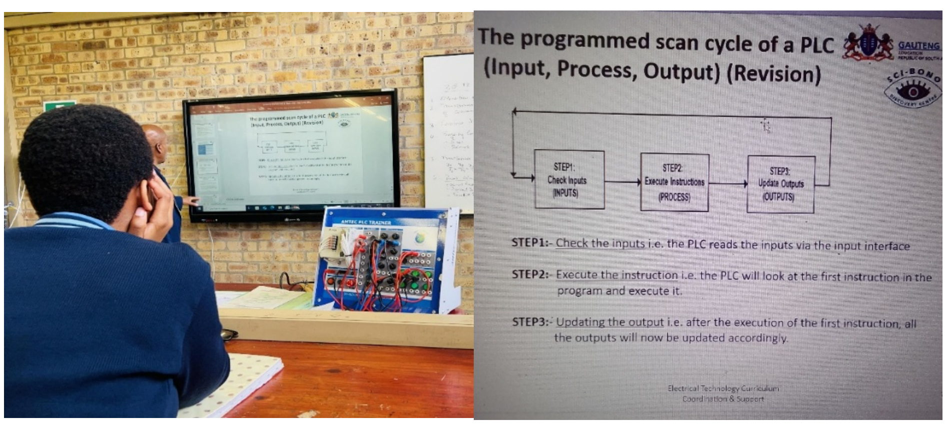


Source: Image taken in the classroom

Despite the logical arrangement, the teacher relied mainly on reading the slides and offered little explanation. There was little learner involvement or link to real-world applications, reducing the depth of pedagogical interaction. According to research, effective TPACK involves more than just showing content, it also requires interactive and learner-centred practices [21]. Teacher A's method demonstrated content and technology alignment but lacked pedagogical implementation. This reveals a gap in teachers' ability to significantly modify information using technology, highlighting the importance of this study in revealing practical flaws in TPACK implementation.

Similarly**,** Teacher C began his lesson by providing a clear historical background on PLCs before concentrating on their applications. He used the common example of an Automated Teller Machine (ATM) to explain the input-process-output model, describing how a debit card and PIN are input, how the PLC processes digital signals, and how the cash withdrawal is output. Learners demonstrated understanding by engaging with the example, which served as a solid Content Knowledge (CK) foundation. The illustration in Figure 3 below shows teacher C undertaken his lesson on PLCs.

Figure 3: Teacher C's lesson.

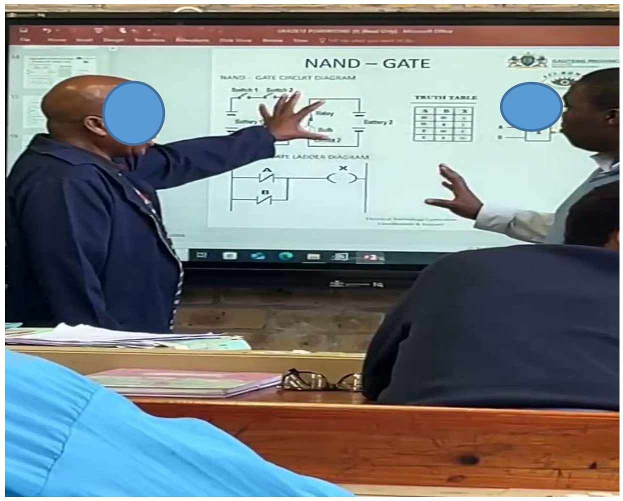


Source: Image taken from Electrical Technology workshop.

Teacher B demonstrated the PLC scan cycle using a PowerPoint slide and a functioning AMTEC PLC trainer. He explained the scan steps, input scan, processing and output scan by pointing to both the slide and the trainer. This well-coordinated use of digital and physical tools demonstrates high Technological Content Knowledge (TCK) and reflects a mixed learning technique that has been successful in Vocational Education [21] .His planning and resource alignment demonstrated good technological knowledge (TK).

However, there was an unusual lack of learner hands-on participation. The teacher controlled the equipment while learners observed, limiting the class to a teacher-centered the norm. This hindered the full implementation of Technological Pedagogical Knowledge (TPK), which focuses on learners' engagement with tools [22]. From a constructivist standpoint, such limited involvement prevents learners from creating knowledge through active problem-solving. While the topic was well provided, the missing chance to encourage experiential learning reduces the depth of understanding, making the class less effective at developing practical skills.

Figure 4: A NAND gate relay-controlled circuit

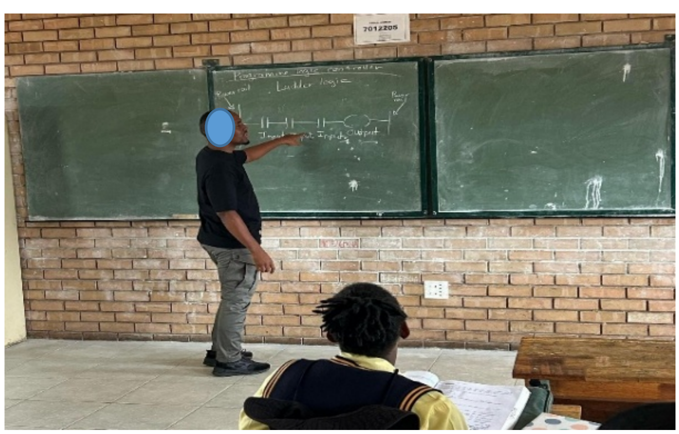


Source: Image taken from Electrical Technology workshop.

In the second part of the lesson, the teacher presented logic gates, namely NAND logic, to explain the difference between hard-wiring and soft-wiring. To demonstrate hard-wiring, he used a NAND logic driven relay circuit example on the board. The inclusion of practical examples helped to clarify abstract concepts, demonstrating good Pedagogical Content Knowledge (PCK). However, the ongoing lack of learner participation in demonstrations highlights the need for more learner-centered methods, particularly in Technical and Vocational Education and Training (TVET), where skill application is critical [23] .This highlights the importance of the current study in advocating for more integrated and participatory teaching methods.

Teacher D used the chalkboard to explain the concept of ladder diagrams in PLC programming. He defined ladder diagrams as a graphical language that depicts control logic with symbols that resemble ladder rungs. He drew a basic ladder diagram on the board, clearly labeling the inputs, outputs, and power rails. This method displayed high knowledge Knowledge (CK) and an attempt to clarify abstract knowledge using visuals, demonstrating some features of Pedagogical Content Knowledge (PCK). However, the class was entirely teacher-centered, with no learner engagement or use of technology resources. According literature, such limited participation hinders learners' ability to develop a profound, transferable understanding of technical systems [24]. Figure 5 below shows the lesson of teacher D.

Figure 5: Teacher D's lesson using a chalkboard.



Source: A photo taken from Power Systems class

The lack of digital tools, such as simulation software, animations, or even PowerPoint slides, revealed a gap in Technological Knowledge (TK) and harmed the ability of teachers to integrate content with interactive pedagogy. Learners just copied from the board, leaving out hands-on or real-world experience. According to recent studies, technical education without digital or practical experience creates a gap between classroom learning and industrial requirements [25]. According to Maseko (2022), passive learning environments frequently result in surface-level understanding. Teacher D's class was well-organized and content-rich, but it lacked the technology integration required to promote deeper learning. This enhances the study's relevance by emphasizing the vital necessity for realistic, technology-enhanced training while teaching PLCs.

Theme 2: Various teaching strategies aimed at supporting learners' understanding of PLC concepts.

When studying how Electrical Technology teachers implemented their TPACK through instructional methods, it was clear that many depended on lecture-based demonstrations assisted by digital aids such as PowerPoint slides. Teachers A, B, and E introduced PLC curriculum with visual aids and, in some cases, real equipment such as a PLC trainer. Despite these attempts, the lessons remained primarily teacher-driven, with little involvement from learners or investigation. For example, Teacher B brought a functional PLC trainer to class but did not enable learners to use it, leaving them passive observers. This teacher-centered method makes limited use of Technological Pedagogical Knowledge (TPK). While visual aids can help awareness, active learner participation is essential in technical education [26]. According to Mishra and Koehler [3, 27], effective TPACK occurs when teachers use technology not only for presentation, but also to allow learners to interact meaningfully with the content. These lessons, while rich in material knowledge, lacked the experiential depth required in vocational settings, revealing a gap in how technology is pedagogically implemented.

To clarify complex PLC ideas, Teacher C used an innovative technique that used narrative storytelling and real-life analogies. For example, comparing Bluetooth-enabled speakers to the PLC scan cycle demonstrated instructional inventiveness and assisted learners in connecting abstract ideas to everyday situations. While this strategy demonstrated good Pedagogical Content Knowledge (PCK), it lacked technology integration completely. No digital simulations or real PLCs were used to supplement the analogies. This absence reduces learners' opportunities for tangible knowledge, especially in technical education where abstract descriptions are insufficient. Kolb's [28] experiential learning theory promotes active involvement, yet this session had students imagining rather than acting. As literature points out, analogies in technical disciplines must be supplemented with visual or hands-on aids to bridge the gap between theory and practice [29]. As a result, while Teacher C's approach was engaging, the lack of technology components undermined the implementation of TPACK and hindered learners' capacity to internalize PLC principles through interaction.

Similarly, teachers like Teacher F used traditional chalkboard methods to teach PLC topics. While this method provided lucid explanations and accurate hand-drawn graphics, it was totally theoretical. Learners were not given access to any real or simulated PLC tools, leaving them to develop mental pictures without practical reinforcement. This approach of training emphasizes the absence of both technological knowledge (TK) and technological pedagogical knowledge (TPK). The gap between theory and practice is especially significant in Vocational Education (VOC). Technical learners require exposure to industry-relevant tools to develop confidence and competence [30]. The static nature of chalkboard teaching fails to actively engage learners and is inconsistent with the principles of effective TPACK, which require technology to be meaningfully integrated into the teaching strategy. While the content was effectively presented, the lack of technical and interactive aspects reduced the lesson's vocational relevance, emphasizing the importance of teacher training in completely implementing TPACK in practical disciplines such as PLCs.

Conclusion

This study explored how Electrical Technology teachers apply Technological Pedagogical Content Knowledge (TPACK) to the teaching of Programmable Logic Controllers. Classroom observations revealed that, while most teachers displayed high content understanding, their use of technology and pedagogy was frequently insufficient. On the same footing, theme 1 uncovered that, while teachers used tools such as presentations, they rarely allowed learners to interact with them directly. For example, teachers projected simulations or exhibited hardware but did not design activities that allowed learners to actively participate. This passive use of technology does not achieve TPACK's goal of learner-centered, technology-supported teaching [4, 31]. The missing chances to connect material and interactive pedagogy underscore the need for improved Technological Pedagogical Knowledge (TPK). Furthermore, Theme 2 also revealed that, while some teachers used a variety of strategies, such as storytelling, analogies and visual slides, the majority of lessons remained teacher-centered. Even when teachers used PLC trainers or visuals, learners were observing rather than participating. The disconnection between theory and practice undermines Vocational Education (VOC) aims and highlights a continuous gap in implementing full TPACK [32].

In conclusion, although teachers possess Content Knowledge and limited Technological Content Knowledge, their practices often lack pedagogical depth. The study highlights a pressing need for professional development that focuses not only on using technology, but on how to integrate it pedagogically. Bridging this gap is crucial for preparing learners with practical, industry-relevant skills and ensuring that the teaching of PLCs aligns with modern vocational education demands.

In research, is always significant to ensure that the researcher do not attempt to influence the study's findings and conclusions. To ensure that the conclusions drawn in this study were not influenced by researcher bias, careful steps were taken during the data analysis process. Firstly, the findings were based on actual classroom observations rather than prior expectations of how Electrical Technology teachers should implement TPACK when teaching. As a result, patterns such as teacher-centred instruction, limited learner participation and the use of technology mainly for presentation emerged consistently across all six schools. This consistency strengthened the credibility of the conclusions. Furthermore, visual evidence was interpreted together with teachers' verbal explanations (verbaims) to ensure that classroom practices were understood within their proper context. Moreover, detailed observation notes were used to capture what occurred during lessons, which helped to avoid selective interpretation of data. Consequently, the themes were developed directly from these repeated classroom practices, particularly the gap between technology use and learner engagement. Therefore, by relying on consistent patterns, multiple sources of data and direct classroom evidence, the study was able to draw conclusions that reflect the real teaching practices of PLCs in Gauteng technical schools rather than subjective judgement.

Credit authorship contribution statement

Authors were solely responsible for all aspects of the research, including the design, data collection, analysis, writing, reviewing, editing, and approval of the final manuscript.

Conflict of interest

The author declares that there are no known financial or personal conflicts of interest that could have influenced the work reported in this paper.

Acknowledgements

The authors would like to acknowledge the support of their university, including the relevant faculty and departmental structures, for providing the necessary resources and guidance throughout the study.

FUNDING INFORMATION.

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Biography of authors

Nzaliseko Dayi is a postgraduate student at the Tshwane University of Technology (TUT) specialising in Electrical Technology. My research focuses on the integration of technology in technical subjects, particularly the teaching of Programmable Logic Controllers (PLCs) and the role of Practical Assessment Tasks (PAT) in improving learners' practical skills. My academic interests are centred on classroom practices in technical schools, teacher knowledge development, and the effective use of technological tools in the teaching of Electrical Technology.

Dr Thokozani Isaac Mtshali is a Research Chairperson in Technology and Vocational Education and Training (TVET) Studies at the Tshwane University of Technology. His research interests focus on TVET education, technical educational technologies, teacher development in technical subjects and special education within the TVET environment. His work contributes to improving teaching and learning in Technical and Vocational Education (TVE), with a particular focus on how technology can enhance learner engagement and skills development.

Lastly, Dr Ramongwane Daniel Sephokgole is a specialist in Agricultural Technology and Sciences. His research interests focus on teaching and learning in the TVET environment, the use of technology in agricultural education and community engagement. His work emphasises the integration of practical and technological approaches to improve learning in technical and vocational subjects.

References

[1] Chang, J., & Liu, D. (2025). Optimising learning outcomes: A comprehensive approach to virtual simulation experiment teaching in higher education. *International Journal of Human–Computer Interaction*, *41*(4), 2114-2134.

[2] Chisango, G., & Marongwe, N. (2021). The digital divide at three disadvantaged secondary schools in Gauteng, South Africa. *Journal of Education (University of KwaZulu-Natal)*, (82), 149-165.

[3] Creswell, J. W. (2018). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (6th ed.). Pearson.

[4] Cunningham, K., Gorman, M., & Maher, J. (2020). The value of using classroom observations as part of a multi-methodological approach to evaluate student engagement in vocational agricultural education. *Educational Research and Evaluation*, *26*(1-2), 4-29.

[5] Dube, L. (2024). Investigating the study habits of undergraduate students during blended learning at a South African University (Master's thesis, University of the Witwatersrand, Johannesburg (South Africa)).

[6] Hamilton, B. (2022). Integrating technology in the classroom: Tools to meet the needs of every student. International Society for Technology in Education.

[7] Harris, J., Mishra, P., & Koehler, M. (2009). Teachers' technological pedagogical content knowledge and learning activity types: Curriculum-based technology integration reframed. *Journal of research on technology in education*, *41(4),* 393-416.

[8] Hazrat, M. A., Hassan, N. M. S., Chowdhury, A. A., Rasul, M. G., & Taylor, B. A. (2023). Developing a skilled workforce for future industry demand: The potential of digital twin-based teaching and learning practices in engineering education. *Sustainability*, *15*(23), 16433.

[9] Horn, M. B., & Staker, H. (2015). Blended: Using disruptive innovation to improve schools. San Francisco, CA: Jossey-Bass.

[10] Hove, D. (2019). A fit-gap analysis of the National Certificate (vocational) Information Technology and Computer Science curriculum against the needs of the South African ICT industry (Doctoral dissertation, Stellenbosch: Stellenbosch University).

[11] Khoza, S. B., & Mpungose, C. B. (2023). Integrating digital technologies in vocational education: Towards relevant and practical teaching. *International Journal of Educational Technology in Higher Education, 20(1),* 45–59.

[13] Koh, J. H. L. (2019). TPACK design scaffolds for supporting teacher pedagogical change. *Educational technology research and development*, *67*(3*),* 577-595.

[14] Maseko, N. D. (2022). Passive learning in technical classrooms: Implications for conceptual understanding in vocational education. *South African Journal of Technical and Vocational Education and Training, 14(2),* 77–90.

[15] Mhlanga, P. T., Khoza, S. D., & Skosana, N. (2023). Exploring the Effectiveness of Practical Assessment Tasks Towards Skills Development in Mechanical Technology Subject. *Journal of Curriculum Studies Research*, *5*(2*),* 136-150.

[16] Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record, 108*(6), 1017–1054.

[17] Muliani, M., Sukarni, S., & Jumadil, J. (2024). English Teachers' Tecnological Knowledge and Some Barriers on It: The Basis for Developing TPACK Teaching Model. *Journal of Languages and Language Teaching*, *12*(1), 499-510.

[18] Pareto, L., & Willermark, S. (2019). TPACK in situ: A design-based approach supporting professional development in practice. *Journal of Educational Computing Research*, *57*(5), 1186-1226.

[19] Qasserras, L. (2024). Transforming training: Evaluating the impact of training of trainers' programs through the lens of transformational learning theory. *Edelweiss Applied Science and Technology*, *8*(6), 6123-6131.

[20] Reaves, J. (2019). 21st-century skills and the fourth industrial revolution: a critical future role for online education. *International Journal on Innovations in Online Education*, *3*(1).

[21] Shahri, N. B. (2020). Effects of Deep Learning Module on Students' Achievement in Programmable Logic Controller Course (Doctoral dissertation, Universiti Teknologi Malaysia).

[22] Shewangizaw, G. (2024). An exploration of Ethiopian Technical and Vocational Training Institute English teachers' views and classroom application of student-centered learning principles. *RATE Issues*, *32*(2).
[23] Taek, P., Madu, A., & Liunima, I. (2024). Analysis of the ability of technological, pedagogical, content, knowledge of senior high school teachers in developing learning tools. *Journal of Survey in Fisheries Sciences*, *11*(3), 10-21.
[24] Tseng, J. J., Chai, C. S., Tan, L., & Park, M. (2022). A critical review of research on technological pedagogical and content knowledge (TPACK) in language teaching. *Computer Assisted Language Learning*, *35*(4), 948-971.
[25] Tzenios, N. (2022). Learner-centered teaching. *International research journal of modernization in Engineering technology and science*, *4*(12), 916-919.
[26] Yin, R. K. (2014). *Case study research: Design and methods* (5th ed.). Thousand Oaks, CA: Sage Publications.