Technological pedagogical content knowledge for twenty-first century learning skills: empowering African teachers for Industry 5.0

Oluwatoyin Ayodele Ajani (a)*

(a) Centre for Excellence in Learning and Teaching, Durban University of Technology, Durban, South Africa

Abstract

The advent of Industry 5.0 marks a pivotal moment in global industry, characterized by the fusion of advanced technologies and human-centred approaches. Embedding Technological Pedagogical Content Knowledge (TPACK) into teacher training becomes imperative in Africa, where the demand for skilled professionals is burgeoning. This study delves into the transformative potential of TPACK for African educators, emphasizing its role in equipping them with skills to prepare students for Industry 5.0 demands. Through a systematic literature review spanning from 2000 to 2024, this research examines TPACK’s multifaceted dimensions and its relevance to twenty-first-century learning skills in Africa. It scrutinizes how emerging technologies like artificial intelligence reshape pedagogical practices and content delivery in African educational contexts. Furthermore, it explores TPACK’s ability to empower teachers in nurturing critical thinking, problem-solving, and digital literacy among students, essential for navigating the complexities of Industry 5.0. The findings underscore the necessity for tailored professional development programs integrating TPACK into African teacher training curricula. Moreover, the research stresses the importance of contextualizing TPACK within the socio-economic and cultural realities of African classrooms to ensure its efficacy. Additionally, the study highlights the pivotal roles of government policies and educational institutions in providing necessary support and resources for widespread TPACK adoption among educators. This research advocates for a paradigm shift in African teacher education, highlighting TPACK's centrality in preparing educators for Industry 5.0 challenges and opportunities. By equipping teachers with adept technology integration skills, African nations can foster innovative and globally competitive learners poised to thrive in the fourth industrial revolution.

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Introduction

The emergence of Industry 5.0 heralds a transformative epoch in the global industry, marked by the seamless integration of advanced technologies and human-centred approaches (Adebesin & Jegede, 2019). This latest industrial revolution builds upon the foundations laid by its predecessors, leveraging cutting-edge innovations such as artificial intelligence, the Internet of Things (IoT), and cyber-physical systems to redefine manufacturing processes and business models (Angeli & Valanides, 2009). As the world undergoes this rapid technological evolution, the role of education in preparing future generations for the demands of Industry 5.0 becomes increasingly paramount (Ajani & Gamede, 2021). In the context of African higher education, the urgency to adapt curricula to align with Industry 5.0 is particularly pronounced. Africa is on the brink of unprecedented economic growth and technological advancement, presenting opportunities and challenges for its education sector (Adebesin & Jegede, 2019). With the continent's youthful population poised to drive innovation and entrepreneurship, a critical need exists to equip students with the knowledge, skills, and competencies necessary to thrive in the digital economy of Industry 5.0.

However, Albion et al. (2018) argue that integrating Industry 5.0 principles into higher education curricula presents a multifaceted challenge. It demands a comprehensive understanding of the technological landscape, pedagogical strategies, and industry trends and a commitment to fostering student innovation and creativity. Furthermore, collaboration between academia, industry stakeholders,
and government agencies is required to ensure that educational programs remain relevant and responsive to the evolving needs of the labour market. Against this backdrop, this study explores the role of technological pedagogical content knowledge (TPACK) in empowering African teachers for Industry 5.0 (Chai et al., 2018). By delving into the transformative potential of TPACK within the African educational context, the research aims to elucidate how it can equip educators with the requisite skills to prepare students for the challenges and opportunities of the fourth industrial revolution (Chang & Ngunjiri, 2016).

The significance of this research lies in its capacity to inform policy and practice in teacher education across Africa. By investigating the intersection of TPACK, emerging technologies, and twenty-first-century learning skills, the study seeks to provide valuable insights and recommendations for developing tailored professional development programs for African teachers (Ajani, 2021). Moreover, by contextualising TPACK within the socio-economic and cultural realities of African classrooms, the research aims to ensure its relevance and effectiveness in preparing educators for the complexities of Industry 5.0. Furthermore, this study aligns with broader efforts to bridge the digital divide and promote equitable access to quality education in Africa. By focusing on the empowerment of African teachers, who play a pivotal role in shaping the future of the continent's youth, the research seeks to create a skilled workforce capable of driving sustainable development and inclusive growth in the digital age (Ajani & Govender, 2023).

This study endeavours to shed light on the transformative potential of TPACK for African teachers in the context of Industry 5.0. The research aims to provide actionable insights and recommendations for policymakers, educators, and other stakeholders invested in advancing education and innovation across the African continent by examining the intersection of education, technology, and economic development (Chigona et al., 2010; Chigona et al., 2018). Thus, this study is guided by the following objectives:

i. To investigate the role of technological pedagogical content knowledge (TPACK) in empowering African teachers for Industry 5.0, focusing on its transformative potential within the African educational context.

ii. To elucidate how TPACK can equip African educators with the requisite skills to prepare students for the challenges and opportunities of the fourth industrial revolution, particularly in fostering innovation, creativity, and digital literacy among learners.

iii. To provide actionable insights and recommendations for developing tailored professional development programs for African teachers aimed at integrating TPACK into teacher training curricula across the continent and ensuring its contextual relevance and effectiveness in preparing educators for the complexities of Industry 5.0.

**Literature Review**

Technological Pedagogical Content Knowledge (TPACK) has emerged as a critical framework for enhancing teaching effectiveness and student learning outcomes in the digital age (Eke, 2019). TPACK represents the intersection of pedagogical, content, and technological knowledge, enabling educators to design and implement innovative instructional strategies that leverage technology to facilitate meaningful learning experiences (Mishra & Koehler, 2006). In the African context, the integration of TPACK into teacher training programs has gained traction as educational institutions seek to prepare educators for the challenges and opportunities of Industry 5.0 (Eke, 2019). However, the adoption and implementation of TPACK in African higher education settings face unique contextual challenges, including limited access to technology infrastructure, inadequate professional development opportunities, and socio-economic disparities among learners (Makoe, 2021).

The evolution of Industry 5.0 has reshaped the landscape of education globally, prompting educators to rethink traditional teaching paradigms and embrace innovative pedagogical approaches (Gibson & Oberg, 2020). In response to the demands of the digital era, educators worldwide have recognised the importance of equipping students with twenty-first-century skills such as critical thinking, collaboration, communication, and creativity (Voogt et al., 2013). TPACK catalyses fostering these skills by empowering teachers to integrate technology seamlessly into their instructional practices while maintaining a deep understanding of subject matter content and pedagogical strategies (Koehler & Mishra, 2009). By leveraging TPACK, educators can create dynamic learning environments that engage students and prepare them for success in the knowledge economy. In the African context, the integration of TPACK into teacher training programs holds immense potential for addressing the pressing need for skilled professionals capable of driving innovation and economic growth (Sayed et al., 2015). However, empirical research on TPACK implementation in African higher education still needs to be expanded, with few studies exploring the effectiveness of TPACK-based interventions in improving teaching practices and student learning outcomes (Ololube, 2016). Despite these challenges, several initiatives have been launched across the continent to promote the integration of technology in education, including developing digital literacy programs, providing ICT infrastructure in schools, and training teachers in TPACK competencies (UNESCO, 2017).

One of the critical challenges facing the effective implementation of TPACK in African higher education is the digital divide, which exacerbates inequalities in access to technology and digital resources (Adesin et al., 2019). In many African countries, rural and underserved communities lack access to reliable internet connectivity, computers, and other digital devices, limiting their ability to fully participate in digital learning experiences (Mlambo, 2020). Addressing this digital divide requires concerted efforts from governments, educational institutions, and international organisations to invest in infrastructure development, provide equitable access to technology resources, and deliver targeted training programs to educators serving in remote areas (Chigona et al., 2018). Despite these challenges, promising examples of TPACK implementation in African higher education offer valuable insights into best practices and effective strategies for integrating technology into teaching and learning. For instance, initiatives like the African
Storybook Project have leveraged digital technology to create and disseminate locally relevant educational resources in multiple African languages, promoting literacy and learning among children in underserved communities (Hennessey & Onguko, 2016). Similarly, teacher training programs like the Intel Teach Program have equipped educators with TPACK competencies through hands-on workshops, online courses, and peer collaboration, improving instructional practices and student engagement (Schooole & Hunter, 2015).

In addition to addressing the digital divide, it is essential to consider the cultural and socio-economic contexts in which TPACK is implemented in African higher education. African countries are characterised by diverse linguistic, cultural, and educational landscapes, necessitating culturally responsive pedagogical approaches that resonate with local communities (Chang & Ngunjiri, 2016). Furthermore, socio-economic factors such as poverty, unemployment, and inequality can impact students’ access to education and their ability to benefit from TPACK-based instructional strategies (Moodley et al., 2017). Therefore, efforts to promote TPACK in African higher education must be informed by understanding the socio-cultural dynamics and systemic challenges facing learners and educators in different contexts. Beyond the African continent, there is a growing body of literature exploring the implementation of TPACK in diverse global contexts and its impact on teaching and learning outcomes. Research studies conducted in countries such as the United States, Australia, and Singapore have demonstrated the positive effects of TPACK-based professional development programs on teacher efficacy, instructional quality, and student engagement (Angeli & Valanides, 2009; Koehler et al., 2014; Chai et al., 2018). These studies have highlighted the importance of ongoing support and mentorship for educators, the need for collaborative learning communities, and the value of integrating TPACK into pre-service and in-service teacher training programs.

Drawing on insights from global research, African higher education institutions can leverage best practices and evidence-based strategies to enhance the integration of TPACK into their teacher training curricula. By adopting an integrated approach that combines technological, pedagogical, and content knowledge, educators can develop innovative instructional practices that cater to students’ diverse needs and learning styles (Schmidt et al., 2009). Moreover, by embracing a culture of lifelong learning and professional development, teachers can stay abreast of emerging technologies and pedagogical trends, ensuring their continued effectiveness in the classroom (König et al., 2020). Conversely, this study underscores the importance of integrating TPACK into African higher education curricula to empower educators for Industry 5.0. By addressing the digital divide, embracing culturally responsive pedagogy, and drawing on global best practices, African countries can equip teachers with the knowledge, skills, and competencies needed to prepare students for success in the digital age. However, to realise the full potential of TPACK, it is essential to invest in infrastructure development, provide ongoing professional development opportunities, and foster collaboration among stakeholders at the national, regional, and international levels (Ertmer et al., 2012).

Moving forward, future research should focus on evaluating the effectiveness of TPACK-based interventions in African higher education, exploring innovative pedagogical models and instructional strategies, and investigating the socio-economic impact of technology integration on student learning outcomes (Ertmer et al., 2012). By generating empirical evidence and sharing best practices, researchers can inform policy decisions, guide curriculum development efforts, and contribute to the ongoing transformation of African education systems in the digital age. Moreover, future studies should pay particular attention to the role of teacher education programs in promoting TPACK competencies among pre-service and in-service teachers, examining the factors that facilitate or hinder the adoption of technology-enhanced instructional practices in African classrooms (Gamede et al., 2022). By identifying barriers and enablers to TPACK implementation, researchers can inform the design of targeted professional development programs and support initiatives that promote teacher efficacy and instructional quality (Albion et al., 2018). Hence, this study provides a comprehensive overview of the theoretical foundations, empirical research findings, and practical implications of integrating TPACK into African higher education. By synthesising insights from African and global contexts, the review highlights the transformative potential of TPACK in empowering educators for Industry 5.0. It lays the groundwork for future research and inquiry in this critical area.

**TPACK for Twenty-First Century Learning Skills: Challenges, Prospects and Trends in African Contexts**

In African contexts, integrating Technological Pedagogical Content Knowledge (TPACK) into education systems faces various challenges yet presents promising prospects and trends for the future. One significant challenge is the digital divide, exacerbating inequalities in technology access and digital literacy skills among students and educators. This gap hinders the effective implementation of TPACK-enhanced teaching and learning practices, particularly in underserved rural communities where infrastructure and resources may be limited (Eshet-Alkalai, 2004). Additionally, cultural and socio-economic factors influence the adoption and implementation of TPACK in African classrooms. Traditional teaching methods and cultural norms may resist change, posing challenges to integrating technology into pedagogy (Chigona et al., 2010). Moreover, disparities in funding and resource allocation across educational institutions further exacerbate these challenges, limiting opportunities for professional development and technological innovation (Udenze et al., 2020).

Despite these challenges, African contexts offer promising prospects for the future of TPACK integration. With the rapid expansion of mobile technology and internet connectivity across the continent, there is increasing potential to leverage digital tools and resources to enhance teaching and learning outcomes (Eke, 2019). Furthermore, initiatives such as open educational resources (OER) and massive open online courses (MOOCs) provide accessible and affordable opportunities for educators to develop their TPACK competencies.
competencies (Omwenga et al., 2016). Moreover, the growing emphasis on entrepreneurship and innovation in African education systems presents a unique opportunity to embed TPACK principles into curriculum design and pedagogical practices. By fostering a culture of creativity, critical thinking, and problem-solving, educators can prepare students for the demands of the twenty-first-century workforce and empower them to drive socio-economic development in their communities (Chikasanda et al., 2012).

In terms of trends, there is a growing recognition of the need for interdisciplinary collaboration and holistic approaches to TPACK integration in African education systems. This includes partnerships between educational institutions, government agencies, private sector organisations, and civil society groups to develop innovative solutions and strategies for leveraging technology in teaching and learning (Tondeur et al., 2017). Furthermore, there is an increasing focus on evidence-based research and evaluation to inform TPACK implementation strategies and assess their impact on teaching effectiveness and student learning outcomes. By collecting and analysing data on TPACK practices and outcomes, educators and policymakers can identify areas for improvement and refine their approaches to technology integration in education (Hennessy et al., 2016).

Theoretical Framework

The theoretical framework for this study is grounded in Technological Pedagogical Content Knowledge (TPACK). This framework integrates technology, pedagogy, and content knowledge to enhance teaching and learning in the digital age. TPACK emerged from the intersection of several theoretical perspectives, including Mishra and Koehler's (2006) seminal work, which proposed the integration of technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK) to address the complexities of teaching with technology. This framework emphasises the dynamic interplay between these three knowledge domains, highlighting the need for teachers to understand how technology can be effectively utilised to support content learning and pedagogical practices.

Figure 1: TPACK

TPACK is rooted in constructivist theories of learning, which emphasise learners’ active engagement in constructing their knowledge and understanding through meaningful experiences. Drawing on Vygotsky's socio-cultural theory, TPACK acknowledges the importance of social interaction and collaborative learning environments in shaping students' cognitive development. Moreover, TPACK is informed by situated learning theories, which emphasise the contextual nature of knowledge and the importance of authentic, real-world experiences in supporting learning outcomes (Gibson & Oberg, 2020). The TPACK framework comprises seven interrelated components: technological knowledge (TK), pedagogical knowledge (PK), content knowledge (CK), pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), and finally, technological pedagogical content knowledge (TPACK). TK refers to understanding the capabilities and limitations of different technologies, while PK pertains to knowledge of effective teaching strategies and instructional methods. CK encompasses subject matter expertise, while PCK involves integrating pedagogical strategies with content knowledge. TCK refers to knowledge of how technology can enhance the teaching of specific subject areas. At the same time, TPK involves the application of pedagogical principles to the use of technology. TPACK represents the intersection of all these knowledge domains, reflecting an integrated understanding of how technology, pedagogy, and content interact to support learning (Finger & Houguet, 2012; Gamede et al., 2022).

In this study, TPACK is particularly relevant for effectively empowering African teachers to prepare students for Industry 5.0. According to Ajani (2023), as the fourth industrial revolution reshapes economies and societies worldwide, educators must adapt their practices to ensure students develop the skills and competencies needed to thrive in a rapidly changing world. TPACK provides
a framework for integrating technology into teaching and learning processes, enabling teachers to leverage digital tools and resources to enhance student engagement, foster critical thinking, and promote collaborative problem-solving. Moreover, TPACK aligns with the principles of twenty-first-century learning, which emphasise the development of skills such as creativity, communication, collaboration, and digital literacy (Harris et al., 2009). By incorporating TPACK into teacher education programs, African educators can equip themselves with the knowledge and skills to prepare students for success in the digital age. This study explores how TPACK can be effectively integrated into teacher training curricula in Africa, focusing on empowering educators to meet the challenges and opportunities of Industry 5.0.

Furthermore, TPACK offers a holistic approach to educational technology integration, emphasising the importance of pedagogical considerations alongside technological and content knowledge. This is particularly important in Africa (Kitchenham et al., 2009), where limited access to technology and infrastructure can pose significant challenges for educators. TPACK enables teachers to make informed decisions about effectively integrating technology into their teaching practices, regardless of resource constraints, by focusing on the intersection of technology, pedagogy, and content. Conversely, Koehler and Mishra (2006) posit that the TPACK framework provides a comprehensive theoretical foundation for understanding the complex interplay between technology, pedagogy, and content knowledge in educational contexts. By integrating TPACK into teacher training programmes, African educators can enhance their capacity to leverage technology to support student learning and prepare them for the demands of Industry 5.0 (Knezek & Christensen, 2010; Koehler et al., 2014). This study will explore the application of TPACK in the African context, focusing on empowering teachers to effectively integrate technology into their teaching practices and enhance student outcomes in the digital age.

Method

The research methodology employed for this study involved conducting a systematic literature review to investigate the role of Technological Pedagogical Content Knowledge (TPACK) in empowering African teachers for Industry 5.0. A systematic literature review allows for a rigorous and comprehensive analysis of existing research findings, enabling the synthesis of relevant evidence to address the research objectives (Tranfield et al., 2003). This approach involved identifying, critically appraising, and synthesising relevant literature published between 2000 and 2024 on TPACK and its implications for teacher education in the African context (Higgins & Green, 2011). The first step of the research methodology was to define the inclusion criteria for selecting relevant literature. This involved identifying keywords and search terms related to TPACK, teacher education, Industry 5.0, and Africa. The search strategy aimed to capture a wide range of perspectives and insights on the topic while ensuring the relevance and quality of the selected literature (Grant & Booth, 2009). Additionally, the inclusion criteria considered the publication date to focus on recent literature that reflects current trends and developments in the field.

Next, the identified literature underwent a systematic screening process to assess its relevance and eligibility for inclusion in the review. This process involved screening titles and abstracts to identify potentially relevant articles, followed by a full-text assessment of selected articles to determine their suitability for inclusion based on predefined criteria (Kitchenham et al., 2009). Articles that met the inclusion criteria were included in the review, while those that did not were excluded with justification. Once the relevant literature was identified, it was systematically analysed to extract key findings, themes, and insights related to TPACK and its implications for African teacher education. This involved coding and categorising the literature to identify patterns, trends, and gaps in the existing research (Braun & Clarke, 2006). Through this process, the research team synthesised the findings to develop a coherent narrative that addresses the research objectives and contributes to the existing knowledge on the topic.

Furthermore, to ensure the rigour and reliability of the review process, the research team employed established guidelines and protocols for conducting systematic literature reviews (Tranfield et al., 2003). This included documenting the search strategy, selection criteria, and data extraction process to enhance transparency and reproducibility. Additionally, the review process involved independent assessment and verification by multiple researchers to minimise bias and ensure the validity of the findings (Higgins & Green, 2011). Overall, this study's systematic literature review methodology enabled a rigorous and comprehensive analysis of existing research (Grant & Booth, 2009), on TPACK and its implications for teacher education in Africa. By synthesising findings from diverse sources, the study provides valuable insights and recommendations for enhancing teacher preparation programs to meet the challenges and opportunities of Industry 5.0 in the African context.

Results

The systematic literature review on Technological Pedagogical Content Knowledge (TPACK) for empowering African teachers in Industry 5.0 yielded several key findings that shed light on the intersection of education, technology, and pedagogy in Africa (Hennessy & Onguko, 2016; Maphalala & Ajanı, 2024). Firstly, the review highlighted the importance of integrating TPACK into teacher training programs to enhance educators’ capacity to effectively leverage technology in the classroom (Koehler & Mishra, 2009). By equipping teachers with the knowledge and skills to integrate technology into their teaching practice, TPACK enables them to create engaging and interactive learning experiences that cater to the needs of diverse learners. Furthermore, the review identified challenges and barriers to implementing TPACK in African education systems. These include limited access to technology infrastructure, inadequate teacher training and support, and a need for alignment between curriculum objectives and technological
resources (Ertmer et al., 2012). Addressing these challenges requires a coordinated effort involving policymakers, educators, and other stakeholders to ensure teachers have the resources and support to integrate technology into their teaching practice effectively.

Moreover, the review highlighted the potential of TPACK to enhance student learning outcomes in the African context. By promoting active learning, collaboration, and critical thinking skills, TPACK-enabled teaching approaches can empower students to become lifelong learners and problem solvers in the digital age (Niess, 2005; Kitchenham et al., 2009; Koh et al., 2013; Konig et al., 2020). Additionally, TPACK facilitates the development of digital literacy skills, which are essential for students to succeed in an increasingly technology-driven world. Another key finding of the review is the importance of contextualising TPACK within the socio-cultural realities of African classrooms. Effective technology integration requires understanding local contexts, including language, culture, and socio-economic factors (Schmidt et al., 2009; Mlambo, 2020). By tailoring TPACK-based approaches to African students' specific needs and interests, educators can create more relevant and meaningful learning experiences that resonate with their lived experiences.

Furthermore, the review highlighted the need for ongoing professional development and support for teachers to integrate TPACK into their teaching practice effectively. Continuous training, mentoring, and peer collaboration can help teachers build confidence and competence in using technology to enhance learning outcomes (Harris et al., 2009). Additionally, investing in infrastructure and resources to support technology integration in schools is essential for ensuring equitable access to educational opportunities for all students. Additionally, the review underscored the importance of fostering collaboration and knowledge sharing among educators, researchers, and policymakers to advance the field of TPACK in the African context (Makoe, 2021). Thus, by facilitating networking opportunities, conferences, and professional communities of practice, stakeholders can exchange ideas, share best practices, and co-create innovative solutions to common challenges (Knezek & Christensen, 2010; Ajani, 2023). Collaborative efforts can also help build a collective understanding of TPACK and its implications for teaching and learning in diverse African contexts.

Moreover, the study identified several gaps and areas for future research in TPACK in Africa. These include the need for more empirical studies to evaluate the effectiveness of TPACK-based interventions in improving teaching and learning outcomes and the need for research on the scalability and sustainability of TPACK initiatives in resource-constrained settings (Niess et al., 2010). Additionally, there is a need for research on the cultural adaptation of TPACK frameworks and models to ensure their relevance and applicability in African classrooms. Based on the findings, this study further underscores the transformative potential of TPACK in empowering African teachers for Industry 5.0 (Moodley et al., 2017). By equipping educators with the knowledge, skills, and confidence to integrate technology into their teaching practice, TPACK enables them to create engaging, interactive, and culturally relevant learning experiences that prepare students for success in the digital age. However, addressing the challenges and barriers to effective TPACK implementation requires a concerted effort from all stakeholders to ensure that teachers have the support and resources they need to succeed.

The literature also revealed the importance of a learner-centred approach in TPACK implementation in African classrooms (Niess, 2005; Ajani & Govender, 2023). By placing students at the centre of the learning process, educators can create meaningful learning experiences that cater to individual needs, interests, and abilities (Angeli & Valanides, 2009). This student-centric approach aligns with the principles of Industry 5.0, which emphasises the importance of human-centred design and personalised experiences. Additionally, the review highlighted the role of educational leadership in promoting the integration of TPACK in African schools. Effective leadership at the school and district levels is essential for fostering a culture of innovation, collaboration, and continuous improvement (Niess et al., 2010; Finger & Houguet, 2012). School leaders play a crucial role in providing vision, direction, and support for TPACK initiatives and advocating for the necessary resources and infrastructure to facilitate technology integration.

Furthermore, the review emphasised the need for a holistic approach to TPACK integration that considers the interplay between technology, pedagogy, and content knowledge (Voogt et al., 2011; Ajani & Govender, 2023). Effective technology integration requires more than just technical skills; it also requires understanding how technology can enhance teaching and learning across different subject areas and grade levels. By promoting interdisciplinary collaboration and professional learning communities, educators can better understand TPACK and its implications for practice (Ololube, 2016). Moreover, the review identified the importance of ongoing assessment and evaluation of TPACK initiatives to monitor progress, identify areas for improvement, and inform future decision-making (Koh et al., 2013). Formative and summative assessments can help educators gauge their effectiveness in integrating technology into their teaching practice and adjust as needed. Additionally, Omwenga et al. (2016) posit that research on TPACK assessment can contribute to developing valid and reliable instruments for measuring teacher competencies in this area.

In conclusion, the findings of the literature review underscore the importance of TPACK in empowering African teachers for Industry 5.0. Sayed et al. (2015) argue that integrating technology, pedagogy, and content knowledge, TPACK enables educators to create engaging, interactive, and personalised learning experiences that prepare students for success in the digital age. However, according to Sehoole and Hunter (2015), realising the full potential of TPACK requires a concerted effort from all stakeholders, including policymakers, educators, school leaders, and researchers. By working together to address challenges and barriers to TPACK implementation, African countries can build a strong foundation for a future-ready workforce and sustainable economic development (Shulman, 1986; Tondeur et al., 2017; UNESCO, 2017; Udenze, 2020; Maphalala & Ajani, 2024).
Conclusion

This study has provided valuable insights into the role of Technological Pedagogical Content Knowledge (TPACK) in empowering African teachers for Industry 5.0. Through a systematic literature review, we have examined the definitions, origins, principles, and concepts of TPACK, highlighting its significance in preparing educators and students for the demands of the twenty-first century. By integrating technology, pedagogy, and content knowledge, TPACK enables educators to create dynamic and engaging learning experiences that foster critical thinking, problem-solving, and digital literacy skills among students. Moreover, the study has underscored the importance of contextualising TPACK within African classrooms' socio-economic, cultural, and educational realities, emphasising the need for tailored professional development programs and supportive policies to facilitate its effective implementation. Moving forward, policymakers, educational leaders, and other stakeholders must prioritise TPACK integration in teacher training programs and curriculum development initiatives. By investing in the professional development of educators and providing the necessary resources and support, African countries can build a strong foundation for sustainable development and economic growth in the digital age. Additionally, further research is needed to explore the impact of TPACK on teaching and learning outcomes in diverse educational contexts and identify best practices for TPACK implementation. Through collaborative efforts and a commitment to innovation and excellence in education, African countries can harness the transformative power of TPACK to create a brighter future for generations to come.

Implications of the study

The implications of this study are far-reaching, extending to various stakeholders involved in education, policy-making, and technology integration. Firstly, for educators in Africa, this research underscores the critical importance of developing and enhancing their Technological Pedagogical Content Knowledge (TPACK) to navigate the challenges and opportunities presented by Industry 5.0 effectively. By integrating TPACK principles into their teaching practices, educators can create more engaging and meaningful learning experiences that better prepare students for success in the digital age.

Moreover, the findings of this study have significant implications for teacher training programs and curriculum development initiatives in African higher education institutions. Educators and curriculum developers must prioritise the integration of TPACK into pre-service and in-service teacher training programs to ensure that future educators are equipped with the necessary skills and competencies to thrive in Industry 5.0. This requires a comprehensive approach that combines pedagogical training with technological fluency and content expertise tailored to African classrooms' unique needs and contexts.

Furthermore, policymakers and educational leaders must recognise the importance of supporting TPACK integration through supportive policies, funding, and infrastructure. Investments in professional development programs, educational technologies, and digital resources are essential to empower educators and students with the tools they need to succeed in the digital age. Additionally, efforts to bridge the digital divide and promote equitable access to technology must be prioritised to ensure all students benefit from TPACK-enhanced learning experiences.

On a broader scale, the implications of this study extend to the future of education and workforce development in Africa. By fostering a culture of innovation, creativity, and lifelong learning, TPACK integration can help African countries harness the full potential of Industry 5.0 to drive economic growth, social development, and sustainable prosperity. Moreover, by preparing a digitally literate and highly skilled workforce, African countries can position themselves as global leaders in the fourth industrial revolution, attracting investment, fostering innovation, and driving inclusive growth.

In conclusion, the implications of this study underscore the transformative potential of TPACK integration in African education systems. By empowering educators with the knowledge, skills, and resources to effectively leverage technology in the classroom, African countries can unlock new opportunities for learning, innovation, and development. However, realising these benefits will require concerted efforts from educators, policymakers, and other stakeholders to prioritise TPACK integration, invest in professional development, and create supportive policy frameworks. Through collaborative action and a commitment to excellence in education, African countries can harness the power of TPACK to build a brighter future for generations to come.

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