Bridging the Digital Divide: The Role of Female Principals in Advancing 4IR in Rural South African Education

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Abstract: Women principals in rural public primary schools have proven themselves to be the change agents despite the numerous constraints in leading the Fourth Industrial Revolution (4IR) in their schools. The purpose of this study was to describe the efforts of women principals leading the 4IR in public rural elementary schools in South Africa. The findings showed that all the respondents had started to integrate 4IR in both administrative and curriculum-related activities although their schools were in the early phases of the 4IR. They indicated that there had been continuous progress in 4IR as teachers and learners are using more e-learning materials, online sites, tablets, smart boards and Wi-Fi to support teaching and learning and in managing the school. In administration, the principals have introduced digital solutions to support school operations such as the South African Schools Administration and Management System (SA-SAMS) and Data Driven District (DDD) systems for administrative purposes, emails and social media for communications, and data analysis to keep track of learners' performance. The women principals are also teaming up with various stakeholders who can assist in this direction such as their SGBs, technologically knowledgeable young teachers, parents, business and community partners. The principals have also shown themselves to be creative and resilient in the face of limited infrastructure and skills development for teachers and themselves. They are committed to continuous learning and professional development and demonstrate this through their development of a culture of innovation and questioning, as well as actively encouraging and facilitating their staff to be upskilled in ways which connect with 4IR skills. The women principals clearly demonstrated their influential roles by inspiring stakeholders to actively participate in the 4IR.

Keyword: Fourth Industrial Revolution, female principals, personalised learning, digital skills, digital communication

Introduction

This study is fundamentally grounded in the escalating momentum and profound implications of the Fourth Industrial Revolution, a phenomenon revolutionising education globally and necessitating adaptive and transformative measures even within under-resourced rural public primary schools in South Africa. The contextual background of this study is anchored in the reality that these schools, historically grappling with infrastructure deficits and multifaceted challenges, are now at a critical juncture where the integration of 4IR technologies and pedagogies is not just an option but an imperative for improving teaching, learning, and school management

practices.

The latest findings by Mataboge (2024) and Wilmot (2024) have highlighted the instrumental role of school leadership, particularly female principals, in spearheading digital transformation in such contexts. This study aligns with the current literature that increasingly acknowledges the centrality of 4IR in education, the specific barriers to its adoption in under-resourced environments, and the unique contributions of female leadership in this domain. It is conducted in a climate where the slow but steady adoption of 4IR tools, such as e-learning systems, interactive whiteboards, Wi-Fi access, and tablets, is becoming more prevalent in rural schools as principals and teachers strive to equip learners with essential 21st-century skills and prepare them for a digitalised future. These technologies are also being recognised as critical for developing skills relevant to the knowledge economy.

Female principals are noted to be particularly resourceful in overcoming challenges through initiatives such as fundraising, engaging with School Governing Bodies (SGBs) to garner support, and focusing on capacity building for teachers and themselves in the use of 4IR tools to support teaching and learning. This is further echoed in recent literature by Ugwu et al. (2025), which emphasises leadership, teacher capacity, and community engagement as key factors in technology adoption in resource-constrained settings. The research question is: How do female principals in rural public primary schools lead the adoption and integration of 4IR technologies, and what are the leadership strategies and challenges that characterise their experiences in resource-constrained educational settings? The need for this study is underscored by the fact that while some progress is being made in integrating 4IR in rural schools, challenges such as lack of training, limited access to devices, and infrastructural issues still impede full adoption. Despite these challenges, the resilience and commitment of female principals are making a difference, gradually transforming their schools and better preparing their learners for the future.

Critical feminist theory is the chosen framework to explore the research problem on women school leaders integrating 4IR technologies in rural public primary schools. In particular, the critical feminist lens requires a focus on gender oppression and gender-specific experiences to be explored when documenting female leaders' trajectories in this specific educational setting to contend with its patriarchal hierarchy and social practices that are not necessarily favouring them (Ferritto, 2024; Liu et al, 2022). Critical feminist theory's attention to experiential epistemology allows female principals to share their own story and counter-stories to narrate their experiences, advocate for gender-equal and inclusive leadership. In addition, it provides important lessons on the intersections between gender, geography and technology and what they intersect with in terms of leadership positions and experiences among rural women in education (Fuller, 2021; Moorosi et al., 2018).

Critical feminist theory in its tradition dates to the first half of the 20th century. Simone de Beauvoir, Kate Millett and Julia Kristeva and others united and began speaking out against patriarchy, on behalf of women (Mullinax et al., 2018). Critical feminist theory is often characterised by others as disunity in principles and being subjective in values. But the attention to oppressed voices is only as useful as the practical ways it can lead to taking up how the female principals experience their context (Allen, 2023). In elevating such voices, critical feminist theory demonstrates the consequences of gendered hierarchies in the school for female principals. The role of critical feminist theory is also to help the researchers historicalise and contextualise policy and the unique needs and experiences of women in leadership roles with a specific attention to

systemic issues that limit their ability to successfully implement 4IR technologies (Marshall, 2020; Pasque & Nicholson, 2023). When using critical feminist theory, in the case of the rural public primary school, we are able to more precisely understand the oppression and the pain they encounter; by this better appreciate their efforts and, as a result, do the most justice to their stories and catalyse the radical change required to build an egalitarian education.

Methods

The study anchored in the interpretivist perspective and used qualitative approaches to provide the description of the different lives of women principals at rural primary schools in South Africa. Hermeneutical interpretivism and phenomenology also lent an appreciation of subjective meanings, which were based on identity and culture, in the researchers' interpretation of social experiences (Sileyew, 2019; Rosenthal, 2018). Axiology, also known as the theory of value in research, highlighted the personal nature of the study since one of the researcher's narratives of her social problems as a woman principal was from her lived experiences. Such an interpretivist model was fit to express the nuances of women principals' 4IR experiences (Creswell & Creswell, 2018). The epistemology, however, was emic in nature and rested on the participants to help understand their world (Nieuwenhuis, 2016). The study used qualitative methods to help the researchers to understand how these principals put 4IR practices in their schools into practice.

Interviews and document analysis allowed the researchers to observe the nuances in their experiences which are essential to how the principals see their role with the 4IR-new technologies (Groenewald, 2004; Poth, 2018). The use of phenomenological strategies such as semi-structured interviews made it easy for the researchers to unearth rich narratives of female principals' personal challenges and success stories. This in-depth study provides useful findings to the policymakers and explain how the female principals could be better supported in their ventures for them to make a meaningful change in rural education in South Africa (Hennink et al., 2020; Neubauer et al., 2019).

Data analysis was done with the hermeneutic circle method that involved reading and thinking of data in a circle to learn new information (Burns & Peacock, 2018; Vieira & de Queiroz, 2017). This is done by reading the entire text and interrogating each sentence to iron out contradictions and derive meaning (Grondin, 2015; de Queiroz, 2017). The authors went through the interviews' transcripts and document reviews to draw out picture statements that the researcher considered relevant to the research questions (Dangal, 2021; Vieira & de Queiroz, 2017). The researchers then organised the relevant information into concepts, which were organised into meaning units that described aspects of the phenomenon as understood by the participants (Dangal, 2021; Van Manen, 2023). A constant search of other ways of understanding allowed a closer analysis of how the female school principals encountered and interpreted the phenomenon (Dangal, 2021; Van Manen, 2023). Eventually, an all-inclusive description emerged from this process, which unified multiple meanings unearthed in the study (Alase, 2017; Dangal, 2021). The researchers recruited 20 female principals at rural public primary schools in Mpumalanga province, who were running coding and robotics classes in their schools, using convenience sampling. This non-probability sampling design was employed because the participants were easily accessible, but the design had a randomisation biases (Etikan et al., 2016; Simkus, 2022).

Qualitative research must be trustworthy if it is to fully capture the participants' experience (Shenton, 2004). Lincoln and Guba's (1985) trustworthiness criteria that include credibility, transferability, reliability and confirmability were used. Credibility called for using existent data collection approaches like audio recording of interviews and member checking interpretations

(Bertram & Christiansen, 2014). Transferability demanded more contextual details so that the readers could tell if the findings could be applied to their own situation (Amin et al., 2020). Dependability is about keeping a record of the research process so that similar exercises could be done, and confirmability is about being objective by grounding the findings in the participants' experience (Amin et al., 2020; Shenton, 2004). The steps taken to make the interview transcripts trustworthy included obtaining the transcripts from good sources that had audio recordings and also using the standardised questioning procedures (Bertram & Christiansen, 2014). In addition, the provision of enough background about the study context will help the readers to place the findings into the context (L. Haven & Van Grootel, 2019). Documentation of the study will allow future researchers to repeat or cross-reference findings from other studies (Hancock et al, 2021).

Research must be ethical to maintain the dignity of the participants and also ensure that obligations to the participants and the scientific community are met (Mirza et al., 2023). When the researcher addresses sensitive issues in a manner that is acceptable to participants following ethical protocols, trust is built and the research integrity is maintained (Israel & Hay, 2006). Ethical issues included informed consent, confidentiality and anonymity and cultural tolerance (Creswell & Creswell, 2018). In this regard, the approval of the university ethics committee and that of the Mpumalanga Department of Education was sought. The participants signed the privacy-ensuring consent forms and were also told that they had the right to withdraw their consent at any time (Parveen & Showkat, 2017; Agunloye, 2019). The researchers also communicated to the participants about the progress of the study and provided them with copies of their responses once the data had been collected (Mirza et al., 2023).

Result And Discussion

Result

All the respondents agreed that they had commenced instituting 4IR facilities in academic administration and curriculum, but they still are in initial stage of implementation. Participant one asserted: "My school is almost there through the assistance of the Department and other initiatives taken by the school and the SGB" (L61-L62). Participant two concurred by stating: "I see our school adopting the Fourth Industrial Revolution by incorporating advanced technologies in the teaching and learning process" (L25-L26). Participant three affirmed by saying: "My school has started with the implementation of 4IR, we are getting there" (L18-L19). Participant 11 indicated that she is gradually implementing the 4IR, but expect faster developments, especially transition to a paperless educational system: "In terms of 4IR implementation, my school is taking it one step at a time. However, I would love to see more progress in integrating 4IR into our educational system, particularly in terms of becoming paperless through the use of tablets" (L23-L25).

Although rural primary schools are making consistent strides in adopting the 4IR, they still have substantial tasks ahead to fully realise their vision of a technologically advanced educational setting. Participant four articulated: "In terms of where our school stands in relation to Fourth Industrial Revolution implementation, I would say we are making steady progress but still have a way to go to fully realise our vision" (L36-L38).

Female principals revealed that their schools, as innovative schools, are staying at the cutting edge of the advent of the 4IR by introducing 4IR innovations on a daily basis by incorporating e-learning, interactive whiteboards, Wi-Fi connectivity and other digital solutions into teaching and learning. Participant fourteen narrated: "I see my school as being at the forefront of this

technological revolution. We have already started to integrate 4IR technologies, such as electronic learning, whiteboard lessons presentation the Internet Wi-Fi connection into our daily operations" (L38-L41). Participant sixteen claimed that these technologies were employed to facilitate teaching and learning processes, enabling teachers to provide more targeted and personalised lessons aligned with the Annual Teaching Plan (ATP). Consequently, this led to improved student learning outcomes. "I use 4th Industrial Revolution to improve teaching and learning process. With the assistance of online learning platforms and also computer skills, I assist teachers in teaching and learning process and also can provide specific focus lesson than the Annual Teaching Plan (ATP)" (L43-L47).

Participant twenty reported that her school is implementing an advanced information technology programme called Edulution. The purpose of this programme is to engage learners in an online interactive learning process using tablets, so enhancing their digital and academic growth. She claimed: "We have an ICT programme running which is called edulution which learners are being taught and learn through tablets" (L35-L36).

The female school leaders are very enthusiastic about the opportunities provided by the tablets and expressed their willingness to experiment and innovate in using digital skills in the classroom, despite the limited resources they had to work with. Participant three narrated: "We have also made concerted efforts to equip our classrooms and learning spaces with the necessary 4IR tools and infrastructure Things like interactive smartboards, tablets, virtual reality headsets, and 3D printers have become integral parts of the learning experience" (L37 – L41).

Rural schools are endeavouring to shift from antiquated manual procedures for duties such as creating schedules, maintaining attendance records, submitting leave applications, and facilitating communication to more streamlined and technologically advanced techniques. Participant five contended: "Our school is trying to shift from the old ways of doing things where things like mark schedules, registers, leave application, mails, messages and other administrative duties were done manually" (L23-L25).

Female principals express a good evaluation of their schools' efforts as they proficiently utilise tablets to teach computer skills and guide learners in conducting research utilising their smartphones. Participant six elucidated: "In terms of rating, I can rate good, the school uses tablets to teach learners computer skills. Learners are being taught on how to google information in their smart phones" (L30-L31).

Female heads of rural public primary schools mention mandatory reform to gain technological know-how to sufficiently motivate and inspire their learners, while also applying fiscal resourcefulness to obtain the necessary technological infrastructure and resources required to implement 4IR in their schools. Participant three outlined: "As female leader in rural public primary schools we have to upgrade our technological skills and knowledge in order to motivate our learners and we have to raise funds for our schools in order to build technological infrastructure and buy technological resources" (L380 – L383). These female principals acknowledge that, in the digital age, computer literacy is essential, especially for them as principals, in order to use sophisticated systems. Participant five explicated: "I need to be computer literate in order to be able to use 4IR as my school is using SA-SAMS and DDD" (L32 – L33).

The female school leaders indicated that the responsibility for their personal professional technological development depends on themselves to maintain their relevance in their career. Participant one specified: "On the Mathematics, Science and Technology (MST) issue, after

realising that I was not getting help after the edu-boards and tablets were delivered and stayed in the school for more than a year, still waiting for training which ended up not coming, I did a "try and error" method" (L167-L169).

Participants receive hands-on access to SA-SAMS's various modules that help them to participate in online courses that help them fine-tune emerging skills in the application of the 4IR in their schools. Participant five declared: "I navigate through the different modules of SA-SAMS. I attend online courses that are offered by DDD teams in order to implement 4IR" (L33 – L35).

The participants recognise that, as managers of the institutions, they also have the responsibility to improve the socio-pedagogical skills of the teaching staff in order to meet the requirements of the 4IR. Participant one narrated: "For the effective use of the gadgets, the school saw the need to capacitate all teachers with basic computer skills for those who were computer illiterate by organising an official from the district office to come and assist the teachers in the computer centre" (L67-L70). Participant three noted the necessity for teachers to be motivated to attend seminars and training regularly as she stated as follows: "The teachers must be encouraged to upgrade themselves too and attend workshops from time to time" (L383–L385).

The female principals as instructional leaders showed understanding that they must ensure that the 4IR amenities are integrated into classroom instruction and learning. Participant three articulated: "This has translated to more innovative and technology-enabled instructional practices in the classroom" (L44-L46). Participant two supported the idea by emphasising the use of digital tools to enable personalised learning as well as the opportunity to be digitally literate and prepared to excel in a digitalised world: "I encourage teachers to use digital tools for enhanced individualised learning, developing the digital literacy of learners and preparing them for future technological advances" (L26-L29).

Participants one and eleven indicated that they make sure that every learner has at least one lesson on the computer per week; this is integrated into the school timetable to allow every grade to access at least one educational programme. Participant 11 declared: "At our school, all learners have computer lessons that are included in the school timetable, with each grade attending for one hour per week to use educational programmes like Matific and Reading Eggs" (L47-L49). Participant one echoed: "The school computer centre is fully functional, and learners from Grade R to Grade 7 are given an opportunity to use a computer once a week" (L70-L71).

Rural public primary schools use tablets to teach learners how to search for information online using their smartphones. They also use overhead projectors to broadcast content lessons, receive training on how to build skills among their staff members, and schedule other extracurricular activities. Participant six elaborated:

The school uses tablets to teach learners computer skills. Learners are being taught on how to google information in their smart phones. The school has overhead projectors that are used to teach the learners different contents, capacity building to the staff and extra mural activities (L31-L33).

One participant stated that they install educational programmes on the parents' mobile devices. Participant 11 claimed: "Additionally, learners bring their cellphones once at the beginning of the year for the installation of these programs, allowing them to continue working at home and during holidays" (L40-L41).

The participant stated that her school is at the forefront of the digital revolution by transforming its classrooms into interactive learning environments, equipped with smart boards,

tablets, and specialist instructional software to enhance learner involvement and learning efficacy. Participant sixteen narrated: "Our school is marching along the pathway into a thoroughly digitalised classroom where digital hardware such as smart boards, tablets and educational software are used to enhance the learning experience of our learners" (L31-L33).

The female leaders understand that many technologies have different purposes to promote teaching and learning in the classroom. Participant two articulated: "Two of our 27 classrooms have smart boards, but teachers use tablets and the few laptops in the staffroom to access and download teaching resources using the school's Wi-Fi connection" (L47 – L48).

Many participants stated that they are utilising technological advancements as a way to communicate with staff and the wider school community. Participant one claimed: "We all have smartphones where communications are sent via WhatsApp and emails" (L87-L88). Participant five supported by stating: "Communicating through emails, holding online meetings, and utilising WhatsApp, enables cost-effective and efficient communication" (L104 – L105). Some female school leasers created school's Facebook page as well as WhatsApp group to engage with learners' and parents' concerns, and where they share photographs and send quarterly performance, acknowledging top achievers. Participant six delineated: "I created face book page where I communicate learners' issues with the parents. I even created a WhatsApp group where I use to communicate with parents. In that WhatsApp I also send best performers on quarterly basis" (L37-L40). As part of the document analysis, I verified the Facebook page and found that it does exist and it is up-to-date. I further viewed their schools' WhatsApp groups, only to find that they are active.

All the study participants reported that using emails and WhatsApp had helped to improve their communication efficiency with the circuits and districts. Participant eleven articulated: "Communication with the circuit or district has also become more efficient through the use of emails and WhatsApp" (L35-L36).

Technology in rural schools has made it easy for the school administration and the supervision of learners' performance. Participant two elaborated: "As a female principal in a rural public primary school, I utilise the 4IR advancements by integrating digital tools into administrative processes and fostering an atmosphere of innovation among staff and learners" (L36-L39).

The principals pointed out the importance and virtue of properly using SA-SAMS for collecting complete school data and for applying DDD for tracking academic progress in order to improve academic performance. Participant five explained: "Being able to utilise SA-SAMS for capturing all the school data, and DDD for tracking academic performance with the aim of improving results, are valuable skills" (L100–L102). Hence, the female principals are regularly reminding and encouraging their teachers to enter learners' marks on SA-SAMS. This has turned the activity from a nag to a fun activity that the schools' staff now love to do. The female principals also encourage the teachers to use the Continuing Professional Teacher Development (CPTD) portal where they can enter their professional development activities and supply evidence of what they are doing to continue learning and developing. Participant one depicted:

I also encourage my teachers to punch learners' marks into the SASAMS, as it is the responsibility of the teacher to record marks, which forces them to use the computers, and they now enjoy it. I further encouraged them to use the CPTD portal to put in their professional development plan and to report to the system about any development activity they partake in (L162-L166).

By getting quotes for school procurement from online proposals or a telephone and email the School Governing Body (SGB) saves time and travelling expenses, also, when it comes to paying of goods and services with the use of online banking. Participant one asserted: "The SGB saves money for traveling to get three quotations for the procurement of school needs; they request quotations online or make calls or emails and get them via email. Payments of goods are done online through online banking, no more traveling" (L236-L239). Participant five holds the same view as she indicated that using electronic transfer for school funds and fee collection, getting quotes online, shopping online and paying electronically makes the financial administration more efficient. "Performing EFT on the school finances, requesting quotations online, purchasing online, and making payments electronically, streamline financial management" (L102 – L104).

Participant eighteen emphasised that her school's confidence in its specialist educators and efficient operations staff has prepared them to adopt the technologies of the 4IR. She believes that her school is capable of achieving greater level of success and continuing to make educational advancements in the future. She stated as follows: "In our school we are equipped, we have skilled educators, we have skilled admin clerk. With the 4IR I think our school is going to do more in the coming years" (L32-L34).

By establishing collaborations with the SGB, the principals successfully implemented digitalisation in their schools. This was achieved by distributing laptops to the senior management team, equipping the administrative office with suitable gadgets and tools, and enhancing connectivity for all teachers to facilitate faster and more efficient workflow. Participant nineteen explained: "Together with the SGB, we have made sure that all SMT members have laptops for administrative duties, the administration office is equipped with all necessary devices such as computers, laptops, Wi-Fi, photocopying machines, and laminators for certificates, and all teachers have access to the internet" (L25-L28).

Female school principals reported that they make good use of the technologies that assist them in the schoolwork and save time in a better way. Participant one elaborated:

We use SA-SAMS for the entire administration of the school, recording of formal assessment activities, attendance of teachers and learners, progress reports, analysis, and teachers' qualifications and specializations, and many more administrative activities. As School Management Team (SMT), we use the DDD to view data and use the analysis when developing Self School Evaluation (SSE), School Improvement Plan (SIP), Subject Improvement Plan (L117 – L122).

Participants utilise the conveniences of the 4IR to promote innovation within the educational community. Participant two narrated: "As a female principal in a rural public primary school, I utilise the 4IR advancements by integrating digital tools into administrative processes and fostering an atmosphere of innovation among staff and learners" (L36 – L39).

All participants reported that they had switched over from manual to completely digital routines for school records. Participant three claimed: "We have transitioned to a fully digitised, cloud-based platform that allows us to seamlessly track and access student data, from enrollment to attendance to academic performance" (L247 – L249).

Participants use the DDD to track the performance of their schools and to access all school data captured through the SASAMS. Participant five affirmed: "Being able to utilise SA-SAMS for capturing all the school data, and Data Driven Districts for tracking academic performance with the aim of improving results, are valuable skills" (L100 – L102). The digital documents accessed

on SASAMS, including attendance records, were consistently updated. The participants confirmed that they regularly upload data on the attendance of both learners and staff members every Friday. The reports on learner performance obtained from the DDD serve as evidence of the participants' utilisation of the DDD.

The process of employees apps for leave and getting approvals by higher-level authorities has been transformed to a digital one, replacing the need by any paperwork. Participant five contended: "Our teachers are trained on the usage of e-leave for leave application. This allows teachers send their leave application from anywhere without waiting until they get back at work" (L39-L41). Participant five reiterated by indicating that teachers can apply for leave online, and other information can be sent and received via email and this also saves time for teachers on the administrative work. She stated as follows: "This allows teachers send their leave application from anywhere without waiting until they get back at work. We are able to send and receive emails" (L39-L41). The e-leave page for both participants were viewed and they were found up to date, with records of leaves taken by the principals, teachers and their members of support staff.

The participants reported that having young teachers enhances knowledge and technological literacy, enabling easy use of digital tools and resources, and filling the Information and Communication Technology (ICT) knowledge gap at the school. Participant eighteen elaborated:

By employing these young educators made things easier for us as educators to do anything that we want. We are able to type, we're able to use gadget that is in this office. We are assisted by them most of the time although we did ICT skills, we know many of the things but because ICT is broad so they are young they know everything they can assist where you think is difficult" (L26-L30).

Teacher profiles were viewed on SASAMS which proved the age of teachers, qualifications and the subjects they are teaching.

The participants reported that they efficiently manage learner admissions, securely stores sensitive personal information, and transfers records from other schools, ensuring accurate and up-to-date information to support the school's operations. Participant twenty stated: I admit learners using the SASAMS. Duplicate documents on the duplicating machine in the school e.g., learner's birth certificates, parents IDs and other documents. Transfer cards for learners leaving the school for some reasons to go to other schools" (L46-L49). Learner information was viewed on SASAMS, all required learner information was provided.

Documents such as strategic plans describing how technology will be implemented in schools and school districts' reports on how 4IR initiatives were progressing were analysed. Training seminar notes and attendance registers were used to track the work of professional development, and formal curriculum documents mapped out how technology should be used in the classroom. Documents of electronic communication between school administrators and stakeholders mapped engagement, and school records catalogued student performance before and after new technologies. Statements of accounts showed spending on tech purchases; minutes of meetings were used to report joint initiatives to improve technology infrastructure.

Discussion

Findings about the current state of adoption of Fourth Industrial Revolution facilities and technologies in South African rural public primary schools revealed an overall mixed, but somewhat encouraging, scenario in which various 4IR facilities and technologies have indeed been

adopted and are in use to some extent in schools. Rural public primary school principals affirmed that some of the technologies were present in their schools, and some of the confirmed 4IR facilities that were in schools had already been used for both the academic administration and academic programmes (curriculum). However, not all these facilities were already integrated into every aspect of the schools' administration and teaching-learning, but the integration process had started. All participating female principals confirmed that they were happy with the current pace of progress of the 4IR implementation process in their schools but wanted to see it move at a faster pace, and they identified aspects like going paperless and improving technology integration processes in their schools as their main focus. Their sentiments about the school's progress on 4IR implementation partially align with what Agyei (2021) found that rural schools in sub-Saharan Africa have started to introduce ICT infrastructure, but complete integration is still some distance away.

Female school principals in these rural schools have in spite of their generally low-resource environments, done commendable and innovative things with technologies like e-learning portals/programmes, interactive whiteboards, Wi-Fi network, tablets, virtual reality headsets, and 3D printers in their schools to help with teaching, personalising learning, as well as supporting the meeting of teaching-related documentation needs (curriculum requirements like Annual Teaching Plan or ATP) and improving learners' performance. School principals have also invested in charging points for classrooms to support the use of these devices at school. This level of innovativeness and clever use of limited resources by female school principals supports what Wilmot (2024) had discovered about the influence female school leaders could have in these rural schools with limited resources towards their innovative use of technologies. Edulution has a model for digital upskilling in rural schools that is integrated into subjects of the basic education curriculum.

Female school principals have confirmed that they are already working towards building and improving their ICT-related competencies and helping to improve their staff ICT-related competencies. The capacity-building related activities in which the school principals have already been involved have included "trial and error" self-facilitated learning as a result of the unavailability of opportunities for staff training on ICT integration (support from ICT experts), self-enrolled online courses, as well as training and capacity-building workshops that have been organised and encouraged by the school management (the school principals) for the staff. Other forms of capacity building for the staff that have been done are improving the computer skills of teachers as a basic ICT literacy requirement for the staff. Female school principals are helping to improve the school staff ICT skills and are ensuring that they continue to do so as they work hard to motivate the staff to acquire and retain new skills as technology for teaching and learning keeps evolving and improving so that they will be able to use the facilities and technologies and improve their use of them. These findings corroborate with the study by Agyei (2021) in which the authors reported that ICT capacity-building of teachers in rural schools was being conducted, both formally and informally.

Female school principals had in their schools replaced some school administrative manual systems with digital and online solutions such as timetables, registers and meeting minutes, and they have also been improving communication with staff, parents, SGBs, and district officials. Digital systems like the South African Schools Administration and Management System (SA-SAMS) and Data Driven Districts (DDD) were already being used to manage learner data and

academic performance and outcomes of the learners, and both SA-SAMS and DDD have resulted in improvement in learners' performance. The use of emails and social media platforms like WhatsApp groups and school Facebook pages to connect and communicate with parents and other stakeholders was also helping to improve parent-school relationships and resulted in improvements in school operations on a day-to-day basis. The ways in which the South African government reported that digital tools were already been used by schools in academic administration (Department of Basic Education, 2022) were confirmed by the findings from the interviews.

The study findings confirm that in South African rural public primary schools, learners already have access to computers and educational software as well as other learning resources, and some of these schools have extended their learning programmes to parents' phones as well to support learning at home. Learners are given the support they need to use technology in the classroom and for home learning, and they have tablets and smartphones provided for research and developing their digital skills. In the classroom, overhead projectors have also been introduced to complement teaching and instruction in support of different kinds of learners in the class. These findings confirm Bahri et al. (2022) assertion about the importance of students' access to devices like computers in schools to improve their digital literacy and other digital skills in support of personalised learning, especially in rural schools.

School principals in the study confirmed that online banking, electronic funds transfer (EFT), as well as electronic procurement and payments have been done in their schools. All these technologies have saved time and resources for the school and the SGB. A collaborative partnership between the school and SGB has helped the school provide SMT members with laptops and to improve and upgrade school facilities such as Wi-Fi network, office equipment, and other technologies used for academic administration in the school. Unfortunately, some of these technologies were not being utilised in schools because of delayed staff training and inadequate staff training on the technologies. This finding was further supported by how the female school principals in this study also stated that as a way of acquiring ICT-related skills and competencies, they have had to do a lot of self-learning to equip themselves to effectively run their schools. Self-motivated female school principals willing to do whatever it takes to bring their schools up to speed and stay ahead with technology despite challenges with lack of resources, training and capacity-building are innovative and professional, and these key characteristics and qualities help to support what Mataboge (2024) found that female school leaders play a significant role in driving innovation with available resources in rural schools.

Viewed in the lens of critical feminist theory, the findings of this study illuminate the intersection of agency, resilience, and transformational leadership demonstrated by female principals as they embrace and lead the integration of 4IR technologies in rural public primary schools. Critical feminist theory, with its emphasis on power, gender, and structural inequalities, provides a framework for understanding the challenges and triumphs of women in positions of authority, especially within patriarchal and resource-constrained educational settings (Hooks, 2000; Morley, 2018). The experiences of the female principals in this study exemplify how women leaders are challenging and subverting traditional gender roles by not only occupying positions of authority in schools but also by actively driving technological change in environments where such change is often assumed to be slow or non-existent.

The findings highlight the transformative agency of these women, as the female principals

took proactive steps to implement 4IR technologies, demonstrating what critical feminist scholars term as transformative resistance against the deficit and static stereotypes associated with women and rural schools (Blackmore, 2013). Their commitment to e-learning, interactive whiteboards, tablets, and virtual reality, despite limited resources and support, is a testament to their ability to mobilise existing assets, form partnerships, and advocate for both staff and learner development. This aligns with the critical feminist understanding of transformative leadership, leaders who work within and against the constraints of their environment to create meaningful change (Blackmore, 2013; Wakefield & Zimmerman, 2020). The female principals' readiness to engage in self-directed learning, facilitate staff upskilling, and experiment with new technologies reflects a professional and institutional growth mindset that transcends gendered expectations of leadership competence and technological proficiency.

Critical feminist theory also sheds light on the structural barriers that can marginalise women and constrain their effectiveness as leaders, such as lack of funding, insufficient training, and patriarchal norms (Smith, 2025). The findings reveal that the female principals are not passively accepting these constraints but actively sought solutions. They organised their own training, motivated teachers, and harnessed community and SGB support to improve digital infrastructure. This active resistance to structural limitations is central to feminist praxis, highlighting how women can be agents of change within and against restrictive systems.

The study's findings further demonstrate how these female principals are redefining leadership in rural education through their focus on collaboration, empowerment, and inclusivity. Efforts to ensure every learner has a computer, install educational software on parents' devices, and utilise digital tools for staff and community communication reflect a feminist ethic of care and collective upliftment (Noddings, 2013). By prioritising digital literacy and encouraging continuous professional development among teachers, the female principals are not only improving educational outcomes but also empowering their colleagues, especially teachers to engage with and benefit from the digital transformation.

From a critical feminist perspective, the progress observed in these schools is significant for promoting gender equity and social justice in education. The ability of the female principals to integrate 4IR technologies into their schools' practices and cultures suggests that women, even in marginalised rural settings, can be effective agents of change and leaders in technological transformation. Their leadership challenges stereotypes about women's technological capabilities and rural schools' capacity for innovation, offering new narratives that can inform policy reforms and support structures designed to meet the needs and leverage the strengths of female leaders.

The findings of this study reveal how female principals in rural South African schools are not only adopting 4IR technologies but also enacting a form of feminist leadership that challenges and transforms structural and gendered barriers. Their agency, resourcefulness, and commitment to inclusive digital transformation stand as a powerful testament to the potential of feminist praxis in educational settings. This understanding emphasises the importance of policies and practices that recognise, support, and amplify the voices and contributions of women leaders in driving technological and educational change

Conclusion

The research successfully demonstrates the influence of female principals in the adoption of 4IR technologies in rural public primary schools. Using qualitative methods, such as interviews

with 20 participants and document analysis, the research shows that rural public primary schools are in the initial phase of digital transformation but have the drive and commitment to continue with this initiative. Female principals play a critical role in bringing innovative technologies and practices, including e-learning platforms, interactive whiteboards, tablets, and advanced administrative systems, to their schools, even in the face of various challenges.

The study provides practical implications for policymakers focused on closing the digital divide in rural education. It highlights the resourcefulness and determination of female principals in rural schools, indicating that with proper support, such as increased investment in infrastructure, accessible and ongoing professional development, and structured training, 4IR technology adoption can be expedited. Policies that support and empower female leadership in rural schools can create a multiplier effect, leading to increased community involvement and more sustainable technological integration in these schools. The study also has implications for practitioners, offering insights into strategies that can be employed to overcome resource constraints and promote a culture of innovation. The experiences and approaches of the principals in the study emphasise the importance of self-motivation, collaboration with school governing bodies, and the creative use of available technologies to improve teaching and administrative practices. The focus on digital literacy for both staff and learners offers a guide for other rural schools that are embarking on or deepening their digital transformation journey.

The study also contributes to theory, particularly in the areas of gendered educational leadership and digital transformation in under-resourced contexts. It challenges prevailing assumptions about the limitations of rural schools and female leadership, showing how agency, adaptability, and professional dedication can help to overcome these challenges. The study also adds to the understanding of how the adoption of 4IR occurs in practice, offering a realistic perspective that can be useful for future research and theory-building in the fields of educational change and technology integration. The research paper provides insights that have practical, theoretical, and policy implications. The study emphasises the transformative potential of female leadership in creating an equitable, innovative, and future-ready education system

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