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# ADAPTIVE ECOSYSTEMIC LEADERSHIP MODEL: A FRAMEWORK FOR SCHOOL CULTURE EVOLUTION IN THE FOURTH INDUSTRIAL REVOLUTION

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## Abstract

The Fourth Industrial Revolution (4IR) is reshaping educational systems worldwide, yet the dominant discourse remains tethered to technological determinism and to leadership models forged in well-resourced settings. What is missing is a theory of how principals lead the cultural work of moving a school from a teaching culture to a learning culture under conditions of material scarcity. Drawing on a qualitative phenomenological study of ten principals from low-quintile (1–3) primary schools in Limpopo, South Africa, who participated in the Sandbox intervention project, this paper develops the Adaptive Ecosystemic Leadership (AEL) model. Data were generated through a focus group discussion with embedded metaphor drawings and one-on-one semi-structured interviews conducted twelve months later and were analysed inductively using Braun and Clarke's six-phase thematic framework. The analysis yielded five themes and a three-layer model comprising a relational-ethical core ("School as Home"), four strategic action domains (contextual intelligence, digital governance, peer-project collaboration, and mentorship-based ICT integration), and an encircling perpetual learning engine. Read through cultural evolution theory and complexity leadership theory, the findings reveal principals acting not as passive selectors of cultural variants but as cultural architects who deliberately engineer transmission regimes, manage variation–selection–retention dynamics, and build systemic resilience. The AEL model contributes a context-sensitive, theoretically grounded framework that extends cultural evolution theory to organisational settings, refines complexity leadership theory, and challenges deficit framings of leadership in under-resourced schools.

**Keywords:** school culture evolution; educational leadership; Fourth Industrial Revolution; cultural evolution theory; complexity leadership; low-quintile schools

## Introduction

Few forces have unsettled the grammar of schooling as quickly as the cluster of technologies gathered under the banner of the Fourth Industrial Revolution. Artificial intelligence, ubiquitous connectivity, robotics, and the blurring of the physical and digital

worlds have, within a single generation, altered what it means to know, to work, and to learn (Reaves, 2019; Kayembe & Nel, 2019). Schools, long organised around the teacher as the principal custodian of knowledge, are now being asked to cultivate something different: a learning culture in which pupils experiment, collaborate, and develop the critical and creative capacities that a volatile economy rewards (Conner & Clawson, 2004; World Economic Forum, 2020). The shift is not cosmetic. It reaches assumptions, routines and relationships through which a school understands itself. It moves a school from a teaching culture to a learning culture, which is, at root, cultural work, and cultural work is stubborn.

A teaching culture positions teachers as the source of information and pupils as recipients who listen, memorise and comply; a learning culture invites pupils to take an active part in their own formation (Conner & Clawson, 2004; Halmaghi & Todăriță, 2023). The distance between the two is measured less in devices than in beliefs. Schein (2010) captured the difficulty when he observed that genuine cultural change requires an institution to unfreeze, unlearn, and relearn what it had taken for granted. This is delicate in stable, well-resourced settings. In schools where electricity is intermittent and an internet connection is a luxury, it becomes a leadership problem of a different order.

The leadership models most often invoked to guide such change were not designed for these conditions. Transformational leadership (Leithwood et al., 2004), distributed leadership, and instructional leadership all emerged largely from stable, comparatively well-provisioned systems and tend to assume an infrastructural and professional baseline that low-quintile schools systematically lack (Spaull, 2015; White & Van Dyk, 2019). In South Africa, the digital divide is stark: only around a fifth of schools have internet connectivity for teaching and learning, and provinces such as Limpopo report large numbers of schools without any computer centre at all (StatsSA, 2022; Kayembe & Nel, 2019; Mojapelo & Modiba, 2021). To import a leadership model that presumes abundance into a context of scarcity is to set principals up to fail, and to mistake the absence of resources for an absence of leadership.

There is also a conceptual problem with how 4IR has been talked about in education. Much of the discourse has been quietly technocentric, treating the arrival of hardware as if it were synonymous with transformation (Mhlanga & Moloi, 2020). This view skates over the cultural labour that any durable change demands. Cultural evolution theory offers a more patient and accurate lens. Rooted in anthropology and the evolutionary social sciences, it conceptualises cultural change as a gradual process in which traits vary, are selected based on their consequences, and are retained and transmitted through social learning (Goodenough, 1999; Mesoudi, 2011; Boyd & Richerson, 2005). Crucially, this study proposes that schools possess a kind of institutional "DNA" that makes change never a one-size-fits-all transplant but an evolution shaped by context, people, and readiness.

Despite the aforementioned cultural evolution theory having rarely been applied to organisations, and even less to school leadership (Brahm & Poblete, 2022). What remains undertheorised is an integrated model that synthesises cultural evolution with complexity leadership theory (Uhl-Bien et al., 2007), that takes the constraints of resource-scarce environments seriously rather than treating them as background noise, and that offers principals something they can actually act upon. Without such a model, policymakers and leadership development programmes risk perpetuating the very standardised prescriptions that founder on the rocks of material scarcity and institutional complexity.

There is a further reason to focus specifically on these schools. It is tempting to read low-quintile areas as sites of deficit, where the proper object of study is what is missing: the absent connectivity, the unfilled posts, the empty computer centre. This study takes the opposite stance. Following the logic that cultural work is most consequential where resources are thinnest, it treats the low-quintile school as a revealing case rather than a deficient one. Where there is little to fall back on, the leadership that nonetheless produces cultural change is laid bare; the strategies are not cushioned by abundance and so can be observed in their pure, improvised form. The principals documented here were not waiting for the infrastructure to arrive before beginning the work of cultural evolution. They were building learning cultures with what they had, and in doing so, they made visible a repertoire of leadership that more comfortable settings may obscure. This paper addresses that aforementioned gap by formulating the following research questions:

**RQ1.** What are the major dimensions of Adaptive Ecosystemic Leadership as practised by principals leading cultural evolution toward 4IR-aligned learning cultures in low-quintile South African primary schools?

**RQ2.** How do the principles of cultural evolution theory (variation, selection, retention and transmission) manifest in the leadership practices of principals navigating 4IR transitions?

**RQ3.** In what ways does the AEL model extend or challenge existing frameworks of educational leadership, and complexity leadership theory in particular?

The study is situated within the Sandbox project, a multi-year initiative that establishes a laboratory for trialling twenty-first-century teaching and learning practices in South African public schools. The study documents the strategic work that principals perform despite material constraints, challenging deficit framings of leadership in under-resourced schools. It also extends cultural evolution theory to the organisational domain by foregrounding the agency of institutional leaders, and it refines complexity leadership theory by specifying the conditions under which adaptive emergence can be enabled in a low-resourced school system.

## Theoretical Framework

This theory is underpinned by two theories: the cultural evolution theory, which provides an understanding of how school cultures change over time; and the complexity leadership theory, which explains how leaders operate within the resulting dynamics of school culture change. The synthesis of the aforementioned theories provides the conceptual foundation for the Adaptive Ecosystemic Leadership model.

## Cultural Evolution Theory (CET)

The study of cultural evolution predates Darwin, with nineteenth-century linguists already noting that languages, like species, are socially transmitted and change gradually over time (Mesoudi, 2011). The formal field matured in the 1980s, when Boyd and Richerson (2005) and others developed quantitative models showing that human culture changes through the same mechanisms as biological evolution: variation, selection and retention (Gidley, 2016; Smolla et al., 2021). Goodenough (1999) defined culture as the criteria for speaking, acting, interpreting and evaluating that people who live and work together acquire through interaction, arguing that cultural knowledge cannot be reproduced unless it is lodged in human minds and transmitted from one person to another through communication.

Three features of the CET theory are relevant to the present argument. First, cultural traits vary: novel practices, beliefs and routines are continually generated, and a population of variants exists at any moment. Second, traits are selected based on their perceived consequences, with effective variants retained and ineffective ones discarded (Mesoudi, 2011). Third, transmission occurs through distinct pathways. Vertical transmission passes traits from one generation to the next; oblique transmission spreads them from non-parental members of an earlier cohort; and horizontal transmission moves them between peers (Goodenough, 1999; Creanza et al., 2017). Social learning, imitation, mentorship, and instruction are the engines of all three, and human beings show a conformist bias, a tendency to adopt the traits most common in their social group (Henrich, 2015).

Goodenough (1999) further observed that small changes at a lower level of organisation can produce large, sometimes discontinuous, changes at a higher level, so that theoretical models must attend to the many organisational levels of a system and their interrelations. Applied to schools, this insight implies that modest adjustments at the level of a grade, a meeting routine or a corridor can ripple upward into the school as a whole. The notion of cultural niche construction, the modification of the material environment in ways that bias future transmission, extends the framework to the physical and digital ecologies that schools inhabit (Brahm & Poblete, 2022). Cultural evolution theory has been applied to anthropological, sociological and psychological phenomena, with only recent application to organisations and school leadership (Brahm & Poblete, 2022; Wilson et al., 2023). This study addresses that lacuna directly. Another distinction sharpens CET theory's focus on leadership. The first concerns the difference between biological and

cultural inheritance. Whereas a person can transmit only one genetic line to an offspring, an individual can learn and carry several cultures at once, acquiring traits not only from parents but from peers and from non-parental elders (Goodenough, 1999). Cultural transmission is therefore richer, faster and more multidirectional than its biological analogue, which is precisely what makes a school a dense web of staff, learners, parents and governors such fertile ground for deliberate cultural design. The second distinction concerns the source of variation. In undirected evolution, variants arise blindly and are filtered by an indifferent environment. Still, cultural systems also admit guided variation, the intentional modification of traits based on individual learning and reasoning (Boyd & Richerson, 2005). It is this capacity for guided variation that opens the conceptual space for a leader to act as an evolver rather than a bystander, a possibility the present study takes up in earnest.

**Complexity Leadership Theory**

Complexity leadership theory (CLT) was developed for organisations operating in the knowledge-intensive, fast-changing conditions intensified by the 4IR (Uhl-Bien et al., 2007). It treats organisations as complex adaptive systems and distinguishes three intertwined leadership functions. Administrative leadership comprises the formal, hierarchical and bureaucratic activities through which leaders plan, coordinate and control to achieve prescribed outcomes. Adaptive leadership is not an act of authority at all but an emergent, informal dynamic that arises from the interactions of agents as they grapple with tension, generating creativity, learning and novel solutions (Baltacı & Balcı, 2017). The third function, enabling (or action-centred) leadership, is the pivot of the theory. Its role is to catalyse conditions in which adaptive leadership can flourish and to manage the "entanglement" between the organisation's bureaucratic and emergent functions (Uhl-Bien et al., 2007). Administrative and adaptive leadership may reinforce or thwart one another; excessive bureaucratic control suppresses adaptive emergence, while insufficient coordination produces chaos. Enabling leadership tailors the two so that they work in tandem. For schools navigating 4IR transitions, CLT offers a way of thinking about how principals can hold the line on order and accountability while simultaneously opening space for the experimentation and grassroots innovation that a learning culture requires.

**Synthesis: Toward Adaptive Ecosystemic Leadership**

Together, the two theories are complementary: cultural evolution theory explains what changes occur in a school and through which mechanisms, but its classical formulations describe population-level processes unfolding across generational time, leaving the agency of identifiable leaders undertheorised. Complexity leadership theory restores agency and attends to how leaders manage the tension between structure and emergence. Still, it offers little account of how cultural traits are transmitted and retained. The synthesis proposed here positions the principal as a cultural architect who engages in directed, rather than undirected, cultural evolution: deliberately engineering

transmission regimes and shaping selection environments to raise the probability of desired cultural outcomes, while enabling the adaptive emergence that no leader can command. This reframing from undirected to directed cultural evolution preserves the evolutionary emphasis on gradual, population-level change while restoring intentionality to its rightful place.

Based on the aforementioned, we proposed a conceptual framework that reads school culture evolution as a directed evolutionary process orchestrated by an enabling leader. The principal cultivates a relational foundation, manages variation selection retention dynamics through engineered transmission regimes, and sustains the whole through continuous learning, an architecture rendered empirically in the Adaptive Ecosystemic Leadership model presented in Section 5.6.

## Literature Review

### School Culture: Definitions and Dimensions

School culture is the set of learned beliefs, values, norms, symbols, and traditions common to those who belong to a school, or, more simply, how members of a school think and act (Northouse, 1999; Narayan, 2016). Its reach is pervasive, such that, as the adage has it, if the culture changes, everything changes (Da Silva Vieira & Barbosa, 2023). Deal and Peterson (2016) describe culture as everything within a school: how people act and dress, what they discuss or avoid, whether they seek out colleagues, and how teachers and pupils feel about the institution. Schein (2004) influentially organised culture into three levels, which are visible artefacts, espoused values such as strategies and goals, and the underlying assumptions that operate beneath conscious awareness. Shared values and beliefs constitute a powerful force that shapes attitudes, motivation, and behaviour, and they often persist long after the individuals who established them have departed. A positive culture is widely held to be both an improvement tool and a coping resource during periods of crisis (Bowers et al., 2017; Narayan, 2016).

### The Fourth Industrial Revolution and Educational Leadership

The 4IR is characterised by the integration of digital, physical and biological systems, diffusing innovation faster and more widely than any previous revolution (Kayembe & Nel, 2019). The 4IR technologies include artificial intelligence, the Internet of Things, robotics, and immersive media. They are all reshaping the skills that schooling must cultivate, shifting the emphasis toward higher-order cognitive, technical, and interpersonal capacities such as creativity, communication, problem-solving, and critical thinking (Chaka, 2020; Reaves, 2019). However, access to these technologies is unequal amongst South African schools. In South Africa, the digital divide aligns with the quintile system, with low-quintile and rural schools least likely to have connectivity, devices, or computer centres (StatsSA, 2022; Mojapelo & Modiba, 2021; Pholotho & Mtsweni, 2016). The COVID-19 pandemic accelerated digital adoption while simultaneously exposing this

divide, as platforms such as Zoom and Microsoft Teams remained out of reach for many rural learners (Mhlanga & Moloi, 2020; Mpungose, 2020). Leadership for the 4IR has accordingly been framed in terms of digital literacy, agility, and the capacity to adapt, though the literature has been slower to examine how such leadership is enacted in contexts where the basic infrastructure is absent.

### Leadership for Cultural Change in Schools

For three decades, change in education has been theorised predominantly through the lens of transformation (Fullan, 2001; Leithwood et al., 2004; Hallinger, as discussed in Baltacı & Balcı, 2017). Transformational leadership has illuminated how leaders inspire and align followers, and distributed leadership has rightly drawn attention to the dispersal of leadership beyond the principal's office. Both, however, have limits in low-quintile contexts. Transformational accounts can understate the structural constraints of resource scarcity, compliance burdens, and community precarity within which principals labour, while distributed leadership can be invoked normatively without specifying the conditions that make genuine distribution possible. The thesis from which this study derives argues that transformation, with its connotation of an abrupt endpoint, sits awkwardly with culture, which is continuous and ever-changing; evolution is offered as the more faithful description (Behling, 2019; Schein, 2010). Existing models, developed in stable and well-provisioned systems, tend to assume a baseline of technological infrastructure, professional development and community capital that low-quintile schools cannot take for granted (Spaull, 2015; White & Van Dyk, 2019).

### Empirical Studies on School Culture Evolution

Empirical work on school culture has tended to document its correlates and associations with effectiveness, teacher job satisfaction, and pupil outcomes—rather than the mechanisms through which it changes. Longitudinal and process-oriented studies that reveal how cultural change is actually accomplished over time remain comparatively scarce, particularly in African and resource-constrained settings. The dominant change-management vocabularies offer stages and steps but rarely a mechanism-level account of how new practices are generated, evaluated and embedded across a school population. The result is a gap between a rich description of what cultural change looks like and a thin explanation of how leaders bring it about under conditions of scarcity. It is precisely this mechanism-level understanding that cultural evolution theory, applied to the lived practice of principals, is positioned to supply.

Where studies do attend to process, they frequently centre on the heroic individual leader, attributing change to vision, charisma, or the force of personality. This framing is doubly problematic in low-quintile contexts. It obscures the distributed, relational and infrastructural labour through which culture is actually built, and it offers little that is transferable, since charisma cannot be taught. A mechanism-level account, by contrast,

identifies the specific, reproducible practices of the cascade ritual, the phased procurement sequence, the participatory budget that any principal might adopt and adapt. By naming the mechanisms rather than celebrating the personalities, such an account converts inspiring exemplars into actionable knowledge, which is what leadership development in resource-constrained systems most urgently requires.

### Research Gap and Contribution

The literature thus leaves three openings. No integrated leadership model synthesises cultural evolution with complexity leadership; there is little mechanism-level study of how school cultures evolve, especially in low-quintile contexts; and the prevailing 4IR discourse remains technocentric, obscuring the relational and ethical work that cultural change requires. This study responds by developing, from the documented practice of principals succeeding under scarcity, the Adaptive Ecosystemic Leadership model—an empirically grounded framework that specifies the transmission regimes, selection processes and relational foundations through which principals lead school culture evolution for a 4IR world.

## Methodology

### Research Paradigm

The study is situated within an interpretivist–constructivist paradigm with a critical edge. Interpretivism holds that organisational realities are constituted through meaning-making and interpretation rather than existing as objective entities independent of human consciousness. At the same time, constructivism emphasises that knowledge is co-constructed between researcher and participants within particular conditions (Guba & Lincoln, 1994; Patton, 2002). A critical sensibility was retained, not as a separate paradigm but as a commitment to interrogating how policy regimes, institutional hierarchies and socio-economic inequality shape what is imaginable and actionable in low-quintile schools (Kincheloe & McLaren, as discussed in the source study). This combination is appropriate because 4IR readiness and school culture evolution are not technical givens but contested, symbolic and relational phenomena.

### Research Design

A qualitative phenomenological design was adopted. Phenomenology offers disciplined access to lived experience here, the experience of principals leading cultural evolution under resource constraints, and seeks the essential structures that constitute that experience rather than measurable intervention outcomes or school-by-school portraits (van Manen, as cited in the source study; McMillan & Schumacher, 2014). The design was participatory, treating principals as knowledge producers rather than mere respondents.

## Context and Setting

The study forms part of the Sandbox project, a multi-year Edhub research and development initiative that establishes a laboratory for trialling twenty-first-century teaching and learning practices in ten low-quintile (1–3) primary schools in Limpopo, South Africa. The project deliberately works within the constraints typical of such schools—overcrowding, resource scarcity and an uneven digital landscape—while exploring the education change agenda. Studying only low-quintile schools limits socio-economic heterogeneity but strengthens internal coherence for theorising leadership under scarcity, the context in which cultural work is arguably most consequential.

## Sampling and Participants

Purposive sampling was used to select the ten principals of the Sandbox-participating schools, who occupy the formal position through which school culture is shaped and institutionalised and who therefore offered rich, experientially proximate accounts (Curtis & Keeler, 2021; Subedi, 2021). All ten took part in the focus group discussion; of these, seven participated in the follow-up interviews twelve months later, one having resigned from the Department of Education and another having requested to be excused. Identifiers were replaced with pseudonyms. Participant characteristics are summarised in Table 1.

**Table 1** *Participant Demographics*

| Pseudonym | Gender | Years of leadership experience | Interview | Selected qualifications |
|---|---|---|---|---|
| Annabel | Female | 7 | Yes | SPTD; ACE (Sciences & Tech); Hons BEd (Education Management) |
| Barbie | Male | 23 | Yes | SPTD; B Tech (Education Management) |
| Christy | Female | 19 | Yes | BA; BEd; ACE (Leadership & Management) |
| David | Male | 16 | Yes | SPTD; ACE (School Leadership & Ed. Mgmt); Hons BEd |

| | | | | |
|---|---|---|---|---|
| Eunice | Female | 17 | Yes | JPTD; ACE (Ed. Mgmt); ACE (Leadership); BEd Hons |
| Fatimah | Female | 10 | Yes | BEd |
| George | Male | 3 | Yes | SPTD; BA (History); BEd Hons (Ed. Mgmt, Law & Policy) |
| Nike | Female | 13 | No | SPTD; B Tech (Ed. Mgmt); ACE (School Leadership); PGD (Labour Law) |
| Tunji | Male | 30 | No | BA (Ed); BEd; MEd (English & History); ACE (Leadership) |

*Note. Nike and Tunji participated in the focus group discussion but were unavailable for the follow-up interviews; their focus group contributions are included in the analysis, but no longitudinal data are available for them.*

**Data Collection Methods**

Two complementary methods were used. The first was a two-hour-and-thirty-one-minute focus group discussion, with embedded metaphor drawings as a participatory visual methodology. Visual methods shift power from researcher to participant and surface tacit, embodied dimensions of leadership that interviews alone may not reach; the drawings functioned as thinking devices that triggered memory and allowed the indirect articulation of difficult experience (Pink, 2001; Chaplin, as cited in the source study). The second was a set of semi-structured, one-on-one interviews of sixty to ninety minutes conducted twelve months after the focus group. The interval was deliberately analytical: principals had returned to their schools, applied insights from the Sandbox engagement, encountered obstacles, and observed outcomes, so that the interviews could revisit the collective themes through the lens of individual, situated practice (Grey, as cited in the source study).

**Data Analysis**

Analysis followed Braun and Clarke's (2006, 2019) six-phase thematic framework, applied inductively and integrating visual and textual data. Interviews were transcribed verbatim and field notes appended; metaphor drawings were digitised and linked to their corresponding transcripts to preserve contextual integrity. Coding proceeded in two parallel streams—open coding of interview data and structured visual content analysis of the drawings and their narration—after which codes were compared through constant comparison, clustered into candidate themes, and refined through recursive review for

internal coherence and external distinction. Themes were finally interpreted in relation to the research questions and the two guiding theories.

### Trustworthiness

Trustworthiness was pursued through Lincoln and Guba's criteria. Credibility was established through prolonged engagement across the multi-year Sandbox frame and through member checking, with participants reviewing transcripts. Dependability was supported by a detailed audit trail and logical, documented reporting. Confirmability was pursued through reflexive memoing and the maintenance of raw data, field notes and coding records, allowing an independent reviewer to trace the analytic path. Transferability was addressed through a thick description of context and participants. Authenticity was strengthened by treating principals as co-interpreters of the visual data, honouring their emic meanings rather than imposing outsider templates (Guba & Lincoln, 1994; Birt et al., 2016).

### Ethical Considerations

Ethical clearance was obtained from the University of Johannesburg, and permission to conduct the research was granted by the Limpopo Department of Education. Participants received a comprehensive information letter and gave written, voluntary consent, with the right to withdraw at any time without penalty. Confidentiality was protected through pseudonymisation and the secure, separate storage of any master list, in line with the Protection of Personal Information Act (POPIA). Findings were committed to be shared with participants as an ethical return on their contribution (Babbie, as cited in the source study; McMillan & Schumacher, 2010).

## Findings

### Overview of Participants and Thematic Structure

Analysis of the focus group discussion and the one-on-one interviews yielded five themes, each addressing a facet of how principals lead the evolution from a teaching to a learning culture for a 4IR world. The first theme concerns how principals conceive of a 4IR-ready school; the second documents the strategic pathways they design for technological transition; the third traces their distribution of leadership across multiple levels; the fourth captures the transformation of leaders themselves; and the fifth presents the integrated model that the foregoing themes compose. Table 2 summarises the themes, their sub-themes and representative evidence.

**Table 2***: Summary of Themes, Sub-themes and Representative Evidence*

| Theme | Sub-themes | Representative evidence |
|---|---|---|

| | | |
|---|---|---|
| 1. 4IR school as a participatory and digitally infused ecosystem | Shared responsibility and visionary ownership; non-hierarchical "open door" policy; digital integration as a cultural norm; conducive and safe physical identity; evidence-based learning evaluation | Fatimah on co-created vision; Eunice on the reconceived principal's office; David on mandatory digital reporting; George on visual signage; Barbie on absenteeism benchmarking |
| 2. Strategic pathways for technological transition and systemic resilience | Phased procurement and capacity building; "knowledge cascade" strategy; proactive "school adaptation" for continuity; pedagogical modernisation via social media; visual norm reinforcement | David and Annabel on phased procurement; Barbie on cascading presentations; Barbie on early recruitment; Barbie on TikTok as resource |
| 3. Evolution through multi-level distributed leadership | Empowering the SMT as co-managers; governance capacity building for the SGB; incentivising parental "buy-in"; liaising with "exo-stakeholders"; financial transparency | David on grade supervision; Barbie on SGB induction; David on flexible report collection; David on PESTLE; David on projected budgets |
| 4. Evolution toward reflective, proactive and relational leadership | Reactive to proactive mindsets; technological self-empowerment; relational practice and "leading by example"; collaborative reflection; humanising leadership through solidarity | David on proactive methods; Christy on the ICT "turning point"; David on shared experience; Annabel on introspection; Fatimah as "mama of the school" |
| 5. The Adaptive Ecosystemic Leadership (AEL) model | “School as home” core; contextual intelligence; digital governance; peer-project collaboration; mentorship-based ICT integration; perpetual learning | Eunice on "school as a home"; David on PESTLE and peer projects; Barbie on lifelong learning |

### Theme 1: The 4IR School as a Participatory and Digitally Infused Ecosystem

Principals did not describe a 4IR-ready school in terms of gadgets. They described an ecosystem resting on shared ownership, flattened hierarchy, normalised digital practice, a cared-for physical identity and a habit of evidence-based reflection.

#### Shared responsibility and visionary ownership

The foundation, principals insisted, is a culture that is co-created rather than imposed. Fatimah explained that her school's guiding documents were drafted collectively:

> *In my school, the vision and mission of the school did not come from me; rather, it must be a shared responsibility. What we did was that we all came together to draft the school vision and mission so that we could understand what we were doing. As long as you understand, you will work toward achieving what we have put down. (Fatimah)*

David made the shared vision physically visible, while George framed collective ownership as the reason implementation came easily:

> *So, we made it very clear that it must be in our blood. It must be owned by us… because they took ownership, they said this is our thing. It's not difficult to implement. (George)*

#### Non-hierarchical "open door" policy

Several principals described dismantling the fear traditionally attached to the principal's office. Eunice contrasted past and present:

> *Since we have the sandbox, our culture has changed a lot… when the principal's office was only for the principal… if you are called to the principal office, you think, no, it means I am in trouble, but now the principal office is a place where we discuss issues… the educators also come with suggestions, and we sit down, we discuss. (Eunice)*

Annabel showed how instant-messaging tools made the door virtual and always open, while David modelled openness through daily briefings and visible reporting, ensuring that every member of staff knew "what happened yesterday" and "what is expected of us today."

#### Digital integration as a cultural norm

Digital tools were described less in terms of their quantity than in terms of their embedding in daily ritual. Fatimah captured the pedagogical rationale:

> *We are now living in the 4IR… Instead of telling learners that a frog has three legs, show them a video of a frog jumping would let them understand better. (Fatimah)*

David institutionalised technology use through a standing expectation that staff returning from any workshop would report back via a slide presentation rather than a private conversation with the principal, making digital practice the default medium of professional discourse.

### Conducive and safe physical identity

The physical environment was treated as an active communicator of culture rather than a neutral backdrop. Eunice described paving the grounds to protect learners' health, framing a clean and safe environment as a precondition for a holistic culture. George engineered the school's identity through signage that pre-emptively enforced norms, from parking to safety, so that visitors "already know that in the school, this is what is expected." David offered the memorable metaphor of the "leaking tap"—the small, ignored infraction that, left unattended, erodes the wider culture of discipline.

### Evidence-based learning evaluation

Finally, principals described a self-reflective, data-informed culture. Barbie illustrated the shift from compliance to genuine evaluation:

> *… you're just not implementing for the sake of… compliance. But you need to monitor… 2020, learner absenteeism was very high. It's now 2023… Evaluation is no longer just about checking boxes—it's about making sure our learners are really learning. (Barbie)*

Annabel described a formal, nine-domain school self-evaluation engaging all staff, embedding evaluation as a collective and cyclical discipline that, in her account, surfaced strengths and weaknesses for collective action.

## Theme 2: Strategic Pathways for Technological Transition and Systemic Resilience

Where the first theme described the destination, the second documents the routes. Principals designed staged, deliberate pathways for integrating technology and building durable institutional strength.

### Phased technological procurement and capacity building

Procurement and training were treated not as separate events but as interconnected phases. David outlined a sequence that began with a trained pilot group and cascaded outward, while Annabel described a layered model moving from equipping educators with devices to ability-grouped training and, finally, a train-the-trainer committee. Both principals candidly acknowledged that infrastructure lagged ambition, so that procurement was incremental and aspirational, kept alive through budgeting for future purchases while maximising current resources.

### The "knowledge cascade" strategy

A recurring innovation was the mandatory post-workshop presentation, an engineered ritual for distributing knowledge through the school. David described its logic:

> *…when you go out for a workshop… you prepare a PowerPoint presentation… The whole staff will sit in that boardroom… So, you report to everyone. And after that, you share that presentation with everyone. So that's empowerment to all. (David)*

Barbie extended the cascade through the governance hierarchy, having each SMT member present a results analysis that she then synthesised for the whole staff, the SGB and ultimately the circuit—building data literacy while aligning understanding across every layer of the school.

### Proactive "school adaptation" for continuity

Principals anticipated disruption rather than merely reacting to it. Barbie treated staff turnover as a foreseeable event requiring pre-emptive systems, recruiting and orienting replacement teachers before incumbents departed so that "we don't lose a day." David reframed the departure of developed staff as a celebration while instituting structured succession, cultivating and mentoring internal successors. George described a comprehensive induction that functioned as a cultural immune system, ensuring that newcomers were "accordingly inducted in terms of the culture of the school."

### Pedagogical modernisation via social media

Principals repurposed ubiquitous, low-cost platforms for professional ends. Barbie actively normalised this:

> *…if you don't have a TikTok, just install TikTok on the school's laptop… there are teachers that are teaching maths and they're bringing in new strategies which can assist you… There is a lot of resources at TikTok. (Barbie)*

George systematised social media for communication, architecting dedicated WhatsApp groups for the SMT, staff and each grade's parents, thereby modernising the school's relational infrastructure at minimal cost.

### Visual norm reinforcement

Finally, principals used persistent physical and environmental cues to embed culture. George's boards acted as a continuous, silent communicator of values and safety expectations; David's displayed mission and vision became the authoritative reference for gatekeepers; and Eunice's paving project communicated care and high standards non-verbally. In an era of digital overload, this low-technology, high-impact strategy provided constant, grounding cues.

### Theme 3: Evolution through Multi-Level Distributed Leadership

Principals did not lead in isolation. They re-engineered governance relationships to distribute not only responsibility but authority, capability and accountability across micro, meso and exo levels.

#### Empowering the SMT as co-managers

David delegated substantive grade-level authority alongside explicit accountability:

> *…each SMT member has got a grade that they are supervising. So, everything about that grade will come from them… the principal is going to hold them accountable for the responsibilities that have been given to them. (David)*

Eunice described co-constructed weekly planning that made the SMT genuine architects of the agenda rather than passive recipients of directives.

#### Governance capacity building for the SGB

Principals invested heavily in educating their own governing bodies. Barbie detailed a systematic induction:

> *I've provided each SGB member with a file… SASA, NEPA, and… relevant policies… Remember, there is a thin line between governance and management… if we don't induct our SGBs fully, they will get into managerial issues… it will create problems. (Barbie)*

David supplemented policy induction with radical financial transparency, projecting budgets and printing bank statements so that the SGB could verify figures and gain ownership.

#### Incentivising parental "buy-in"

Rather than merely demanding support, principals designed structures that made participation valuable. David rescheduled report collection to accommodate working parents; Eunice and Fatimah created concrete volunteer roles, with Fatimah's garden project offering both contribution and material benefit; and Barbie trained parents as reading coaches, conferring status and a clear role in their children's learning. The incentives were psychological and practical rather than monetary respect for time, dignity through contribution, and an empowered role in a child's digital future.

#### Liaising with "exo-stakeholders"

Principals engaged intensively with police, social workers, municipalities and traditional leaders to secure a perimeter of safety. Eunice liaised with the police over drug-related threats; Fatimah coordinated a rapid response to a child-abuse case; George rejected operating "in silos," roping in social development and other departments. Most strikingly, David theorised this work through the PESTLE framework:

> *… there's a theory called PESTLE… your P will be your political environment… the social factors… your T is your technological factors… once you have all the factors here, it's very easy when you plan… these are the contingency plans that I need to put in place. (David)*

**Financial transparency**

Transparency was treated as a foundation for trust rather than a compliance burden. David paired projected budgets with bank statements so that "there's nothing more to complain about because everything is here," and identified this as the means by which he "extinguish[ed] fires." Barbie described an exhaustive participatory budgeting chain through the SGB, finance committee, staff and parents, transforming stakeholders from spectators into co-owners of the financial plan.

**Theme 4: Evolution toward Reflective, Proactive and Relational Leadership**

The fourth theme turns from the school to the leader. Principals described a transformation in how they understood their role, moving from crisis management toward intentional, human-centred practice.

**Reactive to proactive mindsets**

David captured the shift in a single contrast:

> *…we shouldn't leave things to just be out of control and start trying to mend. Sometimes you need to come with proactive methods… That is because of the impact that I had from the sandbox training. (David)*

Barbie linked proactivity to legacy, insisting that culture must be deliberately built so that "even if I've left… my legacy should still remain."

**Technological self-empowerment**

Principals understood that they could not credibly mandate digital integration without upskilling themselves. Christy described a turning point:

> *The sandbox training on ICT was a turning point for me—it transformed how I engage with technology… I remember thinking, 'Wow, I can actually google what we're learning, and it all connects.' (Christy)*

Barbie pursued empowerment through proactive peer benchmarking, visiting a fellow principal to "learn more and compare notes," framing learning as continuous and self-directed.

**Relational practice and "leading by example"**

Principals located authentic change in relational integrity and embodied action. David articulated this most explicitly:

> *When they cry, we cry together. When we eat, we eat together… These little things, they make us a good team, and it ensure that the culture that we have created here, they will protect it without you knowing. (David)*

George learned that imposition fails but co-creation endures, attributing easy implementation to having let stakeholders "have inputs."

### Collaborative reflection

Reflection was reframed as a communal rather than solitary exercise. Annabel observed that "you cannot improve on your own." Barbie described peer principal networks as spaces where "your mind widens up… your wings now start to open," providing both practical solutions and psychological support.

### Humanising leadership through solidarity

Finally, principals cultivated solidarity and a sense of shared humanity. Eunice described informal bonding—shared birthday meals—that strengthened relational bonds and morale; George tied the school's success to the holistic wellbeing of its people; and Fatimah described herself, tellingly, as the "mama of the whole school," a learned leadership identity centred on care.

### Theme 5: The Adaptive Ecosystemic Leadership (AEL) Model

The preceding themes do not stand apart; they compose a coherent model. The Adaptive Ecosystemic Leadership model (Figure 1) was extracted from, rather than imposed upon, the data. It posits that leading a 4IR-oriented culture of learning requires principals to function as architects of a living ecosystem rather than managers of an institution, and it comprises three conceptual layers.

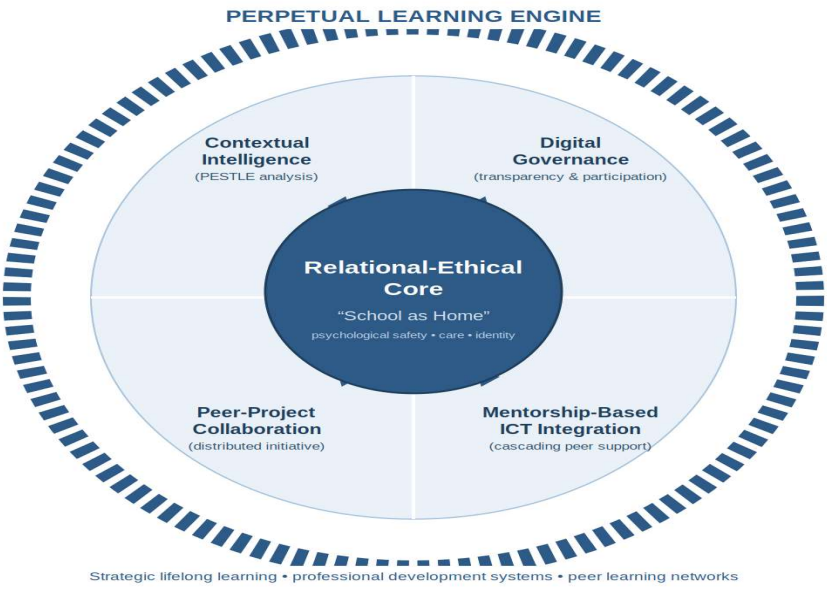


*Figure 1. The Adaptive Ecosystemic Leadership (AEL) Model.*

At the heart of the model lies the relational-ethical core, the "School as Home" ethos. This is the non-negotiable cultural bedrock—psychological safety, mutual care, and collective identity that principals consistently described as a prerequisite to any strategic action. Eunice named it directly when she urged that principals "make the school like a home, not like an institution," so that "everybody has to take part… and everybody will be appreciated."

Surrounding the core are four interconnected strategic action domains that operationalise the culture shift. Contextual intelligence, operationalised through the PESTLE framework, provides a diagnostic lens that renders subsequent action locally relevant. Digital governance translates analysis into transparent, participatory and efficient practice, modelling the 4IR world while building institutional trust. Peer-project collaboration distributes leadership and builds capacity by pairing and grouping staff and principals around shared tasks. Mentorship-based ICT integration ensures that technological change is sustainable, replacing the "device dump" with embedded, cascading peer support. These domains are not sequential but iterative and mutually reinforcing: digital tools facilitate collaboration, collaborative projects address contextual challenges, and mentorship spreads digital competence.

Encircling and permeating the whole is the perpetual learning engine—the principal's own lifelong learning, the institutionalisation of professional development, and the cultivation of peer learning networks. Barbie expressed its disposition plainly: "being a principal doesn't mean you know everything. You are still a learner, and you will continue to be a lifelong learner." This engine ensures that the ecosystem does not stagnate but continually absorbs new knowledge and feeds it back into the core and the action domains. Figure 2 maps how the variation–selection–retention mechanisms of cultural evolution are distributed across these components.

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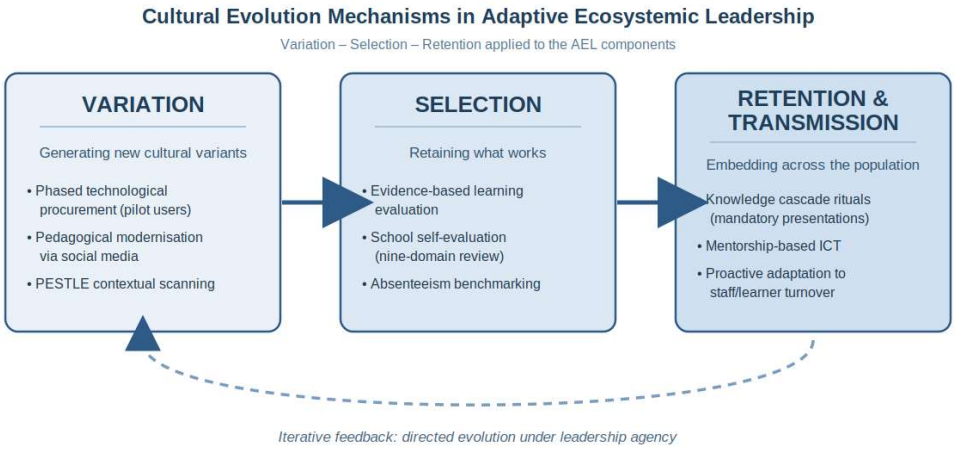



*Figure 2. Cultural evolution mechanisms in school leadership, applied to the AEL components.*

## Discussion

The findings invite a theoretically disciplined reading that moves beyond description to expose the generative mechanisms underpinning principals' cultural work. Interpreted through cultural evolution theory and complexity leadership theory, the five themes reveal principals not as passive recipients of change but as cultural architects engaged in directed evolution.

### Reimagining 4IR School Culture: Beyond Technological Determinism

The first theme departs sharply from technocentric narratives. When Fatimah insisted that vision "must be a shared responsibility" and David inscribed the mission on entrance walls, they were operationalising a core principle of cultural evolution theory: cultural traits persist not through coercion but through successful transmission and internalisation across a population (Boyd & Richerson, 2005). Co-creation reverses the usual directionality of vertical transmission, positioning all stakeholders as co-producers of the cultural repertoire and generating what Henrich (2015) terms conformist bias. George's observation that collaboratively developed culture becomes "our thing" and is "not difficult to implement" describes the evolutionary advantage of participatory design: variants that emerge through collective deliberation enjoy higher transmission fidelity and greater resistance to decay than those imposed by fiat.

Eunice's reconfiguration of the principal's office, read through complexity leadership theory, is more than improved communication; it is the deliberate cultivation of adaptive leadership conditions (Uhl-Bien et al., 2007). By lowering the activation energy for informal interaction, the open door functions as an enabling constraint that shapes the

probability of adaptive responses without prescribing their content. David's mandatory digital reporting, meanwhile, exemplifies oblique transmission, bypassing the principal as sole knowledge broker, while the principals' heavy investment in physical orderliness illustrates cultural niche construction—the modification of the material environment to bias future transmission (Brahm & Poblete, 2022; Schein, 2004). The 4IR school, in this formulation, is defined not by its technology but by its capacity to construct mutually reinforcing physical and digital ecologies.

**Designing Evolution: Strategic Pathways as Engineered Transmission Regimes**

The strategic pathways of Theme 2 are best understood as engineered transmission regimes—deliberately designed systems for controlling the variation, selection and retention of cultural traits. Phased procurement functions as a protected variation strategy: a small subpopulation experiments with a novel trait, adapts it to local constraints and generates evidence that lowers the perceived risk for later adopters. The knowledge cascade is a sophisticated intervention into the school's cultural replication machinery; the mandatory presentation deepens the presenter's own encoding, exposes the whole staff simultaneously—inviting frequency-dependent selection—and creates a persistent artifact for newcomers. Proactive adaptation addresses the gravest threat to cultural sustainability in high-turnover contexts: transmission failure at generational boundaries (Henrich, 2015). Barbie's early-recruitment protocol and David's succession grooming are, in evolutionary terms, deliberately engineered vertical transmission pathways that anticipate and absorb population turnover. Barbie's repurposing of TikTok, finally, reveals principals as active cultural importers who leverage ubiquitous technologies to circumvent structural constraints on innovation—a finding that challenges deficit discourses about under-resourced schools (Boyd & Richerson, 2005).

**The Principal as Ecosystem Orchestrator**

Theme 3 reveals a multi-level orchestration in which principals re-engineer governance relationships rather than merely delegating within them. David's delegation of grade-level authority alongside accountability creates what complexity leadership theory terms enabling entanglement, leveraging bureaucratic structure to support rather than suppress adaptive problem-solving (Uhl-Bien et al., 2007). The counter-intuitive investment in SGB capacity building is best read as governance niche construction: by educating their own oversight body, principals convert an unpredictable environmental actor into a reliable resource that can mobilise buy-in and defend the school's direction. Parental incentivisation, in turn, applies reciprocity-based cooperation models (Henrich, 2015), restructuring the cost–benefit landscape of engagement so that participation becomes individually rational—reframing "hard-to-reach" parents as a problem of institutional design rather than parental deficit. David's explicit use of PESTLE is especially significant: it theorises contextual intelligence, transforming tacit experiential knowledge into an

explicit, teachable analytical protocol and demonstrating that "understanding context" can be systematically operationalised rather than left as a generic competency.

**The Evolution of the Evolver: Leadership Learning as Identity Transformation**

Theme 4 documents principals who are themselves evolving as cultural agents. The shift from "trying to mend" to "proactive methods" is ontological, marking the transition from respondent to architect—from being subject to selection pressures to consciously directing the institution's adaptive capacity. This extends cultural evolution theory, which has focused largely on unconscious, population-level processes, by documenting intentional cultural evolution orchestrated by identifiable agents. Technological self-empowerment operates as costly signalling (Henrich, 2015): principals who visibly struggle with and master new tools send an honest, credible signal about the value they place on integration, more influential than any directive. Relational solidarity, far from being a soft skill, functions as hard cultural infrastructure, since transmission is mediated by trust and emotional connection; principals who invest in relationships increase the probability that their advocated variants will be attended to and retained. Collaborative reflection constitutes a distributed intelligence system and a cultural recombination engine, exposing principals to variants from other contexts. Finally, the values-inflected vision articulated by Fatimah and George complexifies cultural evolution theory: the fitness landscape on which school cultural traits compete includes not only instrumental outcomes but normative criteria, rendering evolution toward a 4IR learning culture a moral project as much as a technical one.

**The AEL Model: Theoretical Synthesis**

The AEL model synthesises and extends both traditions. From cultural evolution theory it draws attention to transmission mechanisms, selection processes and population dynamics, while extending the theory by foregrounding the agency of leaders in intentionally engineering transmission regimes—a dimension undertheorised in accounts focused on generational time. From complexity leadership theory it incorporates the administrative–adaptive–enabling distinction: the "School as Home" core and peer-project domain create conditions for adaptive emergence; digital governance and contextual intelligence reframe administrative leadership through transparency and diagnosis rather than command; and the model as a whole casts the principal as an enabling leader orchestrating entanglement. The findings both support and refine the evolution–transformation distinction. They support it in that principals described incremental, iterative change consistent with evolutionary models; no principal claimed a sudden revolutionary break. Yet they were not passive selectors of random variants but intentional, design-oriented agents. The relevant distinction, the model suggests, is therefore not between evolution and transformation but between undirected evolution and directed evolution—the intentional modification of transmission regimes and selection environments to raise the probability of desired outcomes.

This refinement matters for the wider field. Much educational change scholarship has oscillated between two unsatisfactory poles: a transformational rhetoric that promises rapid, leader-driven rupture, and a critical realism that emphasises how structures resist and absorb reform. Directed evolution charts a course between them. It honours the structural and temporal realities that frustrate transformation—culture is sticky, change is slow, and inherited substrates cannot simply be overwritten while preserving a robust account of leadership agency. The principals in this study did not wait for a participatory culture to emerge; they engineered the rituals, structures and incentives that made it more probable. Equally, they did not impose change by decree; they shaped the conditions under which staff and community would generate, test and retain new practices of their own accord. The model thus reconciles agency and structure not by privileging one over the other but by locating the leader's influence precisely at the level of the transmission regime and the selection environment, where intention can bend the trajectory of an otherwise gradual process.

### imitations and Future Research

Three limitations bound these claims. The model derives from a single province, school phase and quintile band, so its transferability to secondary, well-resourced or other national contexts requires empirical investigation. Its components are described but not operationalised as measurable constructs; future work should develop and validate instruments to assess AEL capabilities and their relationship to school outcomes. And the findings represent principals' self-reported practice, triangulated across the focus group and interviews but not subjected to sustained observational validation. Longitudinal, observational and comparative studies would test, refine and extend the model.

## Conclusion and Implications

### Summary of Findings

This study examined how principals lead the evolution from a teaching culture to a learning culture amid the demands of the 4IR in schools where material scarcity is the norm. The answer is the Adaptive Ecosystemic Leadership model: a relational-ethical core surrounded by four mutually reinforcing strategic action domains and sustained by a perpetual learning engine. Across five themes, principals emerged not as managers of instruction but as architects of a learning ecosystem who engineer transmission regimes, manage variation–selection–retention dynamics, and build systemic resilience despite constraint.

### Theoretical Implications

Theoretically, the study extends cultural evolution theory into organisational settings by documenting intentional, agent-directed evolution; it refines complexity leadership theory by specifying the institutional conditions distributed authority, psychological safety, transparent information flows—that enable adaptive emergence. It challenges

technological determinism by demonstrating that 4IR readiness is achieved through cultural and relational work rather than hardware alone.

### Practical Implications for School Leadership

For practice, the model suggests several concrete moves: institutionalising an open-door policy that flattens hierarchy; pursuing phased technological procurement coupled with cascading training; establishing structured knowledge-transmission rituals such as mandatory post-workshop presentations; and grounding strategic planning in PESTLE-based contextual analysis. Each is low-cost and within reach of resource-constrained schools.

### Policy Implications

For policy, the findings argue for digital-integration strategies that fund cascading capacity building rather than device distribution alone, for explicit requirements and support for SGB and SMT capacity building, and for the formal recognition and resourcing of peer learning networks among principals, which this study found to be among the most consequential sites of leadership learning.

### Implications for Leadership Preparation and Development

For leadership preparation, the model implies a rethinking of principal training programmes so that they cultivate relational and adaptive competencies alongside technical and managerial ones, and so that they treat contextual intelligence as a teachable, operationalisable discipline rather than an assumed attribute.

### Concluding Statement

In a 4IR world, the principal is less a controller of instruction than a curator of a learning ecosystem. The AEL model offers a theoretically grounded, empirically derived and practically actionable account of how that curation is accomplished—even, and especially, where resources are scarce.

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