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Transformational School Leadership And Digital Innovation In Biology Education: A Qualitative Case Study From A Rural Indonesian Secondary School

Salvinus Hadu
Master's Program in Biology Education, Postgraduate Faculty, Universitas Patompo, Makassar, Indonesia
Ahmad Hasyim
Master's Program in Biology Education, Postgraduate Faculty, Universitas Patompo, Makassar, Indonesia
Syarifudin
Postgraduate Faculty, Universitas Patompo, Makassar, Indonesia

Corresponding Author: ahasyim@unpatompo.ac.id

Abstract

School leadership is widely regarded as a decisive factor in the success of digital transformation in education, yet qualitative evidence on how principals translate transformational leadership behaviour into concrete support for technology-based science instruction, particularly in resource-constrained, rural school settings, remains limited. This study analysed the transformational leadership of a public senior secondary school principal in promoting digital-based innovation in Biology learning, using a qualitative case-study design. Informants comprised the principal, the vice-principal for curriculum, Biology teachers, other teachers involved in digital-learning development, and Grade XII science students, selected through purposive sampling. Data were collected through in-depth interviews, non-participant observation, and documentation, and were analysed through data condensation, data display, and conclusion drawing/verification, with credibility strengthened by source and technique triangulation and member checking. Findings show that the principal's transformational leadership was expressed through all four classic dimensions: idealized influence, evident in the principal's own commitment to and modelling of technology-supported instructional improvement; inspirational motivation, expressed through sustained encouragement and

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articulation of a shared vision for digital-based learning; intellectual stimulation, reflected in the principal's encouragement of teachers to experiment with digital media and jointly solve implementation problems; and individualized consideration, shown through differentiated coaching that matched support to each teacher's digital competence. Teachers responded positively to this leadership, adopting tools such as PowerPoint, YouTube, and instant-messaging platforms in Biology instruction, although digital competence varied considerably among staff. Supporting factors included the principal's commitment, teacher enthusiasm, and the availability of digital devices and internet access, while inhibiting factors included unstable internet connectivity, limited teacher digital competence, and constrained student internet quotas. The principal addressed these barriers through training, mentoring, supervision, infrastructure development, and the cultivation of a collaborative, appreciation-based school culture. The study concludes that transformational leadership functions as a critical enabler of digital innovation in science instruction, a pattern with relevance to school systems worldwide that are navigating similar digital-transformation demands under resource constraints.

Keywords: Transformational Leadership; School Principal; Digital Learning Innovation; Biology Education; Qualitative Case Study.

INTRODUCTION

Digital transformation has become a defining priority for education systems worldwide, reshaping how teachers design instruction and how school leaders organise the human and technical resources that support it. In Indonesia, national policy instruments such as the Merdeka Belajar (Independent Learning) framework and the Merdeka Mengajar teaching platform have reinforced the expectation that teachers move from being the sole source of information toward becoming facilitators of technology-mediated, student-centred learning. Yet this shift rarely occurs automatically: it depends heavily on school leadership, teacher capacity, and an organisational culture that actively supports innovation. Transformational leadership, commonly characterised through idealized influence, inspirational motivation, intellectual stimulation, and individualized consideration, has been identified across a growing international literature as a central mechanism through which principals convert digital policy aspirations into classroom-level change (Ahsan, 2025; Al-Ghozali et al., 2025).

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The need for digital innovation is particularly acute in Biology, a subject that routinely requires learners to grasp microscopic structures, genetic mechanisms, and ecological processes not directly observable in the classroom. Digital media such as video, simulation, and interactive presentation can make such content more concrete, yet their pedagogical value depends on teachers' willingness and capability to use them purposefully, which in turn depends on the leadership support they receive. A growing body of international research links principals' digital transformational leadership to teachers' technology beliefs, technical skills, and pedagogical integration of technology (Schmitz et al., 2023; Berkovich et al., 2025), and to the strategic direction of school-wide digital transformation more broadly (Navaridas-Nalda et al., 2020). What remains comparatively scarce is fine-grained qualitative evidence of how principals in under-resourced, rural contexts operationalise each dimension of transformational leadership to drive digital innovation within a specific subject area.

This study therefore examined the transformational leadership of a public senior secondary school principal in promoting digital-based innovation in Biology learning, addressing four questions: (1) how is the principal's transformational leadership practised, (2) what strategies are used to promote digital-based innovation in Biology learning, (3) how do teachers respond to that leadership, and (4) what factors support and inhibit implementation, and how does the principal address the barriers encountered. Because rural, resource-constrained schools worldwide face broadly similar tensions between digital-transformation ambitions and limited infrastructure and teacher readiness, the findings speak to an internationally recognised challenge: how principals can act as catalysts for sustainable technology integration when resources are scarce.

LITERATURE REVIEW

Transformational Leadership in Schools

Transformational leadership is conceptualised through four interrelated dimensions: idealized influence, modelling the values and behaviours expected of followers; inspirational motivation, articulating and sustaining a compelling shared vision; intellectual stimulation, encouraging creative, critical engagement with problems; and individualized consideration, attending to followers' distinct needs and capacities (Ahsan, 2025). In school settings, principals who enact these dimensions function less as administrators and more as agents of change who build an organisational culture receptive to innovation, including the innovations required by

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digital transformation, even where they simultaneously carry dual administrative and instructional roles (Al-Ghozali et al., 2025).

Principal Digital Leadership and Technology Integration

A dedicated strand of research examines transformational leadership specifically in relation to digital transformation. Navaridas-Nalda et al. (2020) found that principal leadership exerts a strategic influence on how schools plan and enact digital transformation, while technical support and school climate condition how effectively digital resources are used. Schmitz et al. (2023) showed that principals' transformational leadership is positively associated with teachers' beliefs about technology, their technical skills, their pedagogical skill in using technology, and the depth of technology integration achieved in the classroom. Complementary evidence indicates that principals' digital transformational leadership is linked to teachers' commitment and to overall school effectiveness (Berkovich et al., 2025), and that such leadership functions as a catalyst for digital-learning implementation at the school level (Handayani et al., 2025).

Transformational Leadership and Digital Innovation: Prior Findings

A recent systematic review confirms that transformational leadership is consistently associated with digital innovation across diverse educational settings, though the specific mechanisms vary with context (Kausar et al., 2025). At the school level, such leadership has been shown to encourage teachers' innovative behaviour (Erlisa, 2024), to strengthen instructional leadership through digital transformation in the post-pandemic period (Nurrochman et al., 2023), and to enhance teachers' digital literacy specifically (Juniarti et al., 2025). Complementary evidence situates transformational leadership within a broader model of teacher empowerment in fourth-industrial-revolution education (Yufita & Sihotang, 2020) and within strategies used to raise the quality of digital-era instruction (Kencana & Iraynida, 2024). Taken together, this literature indicates that principal leadership, teacher capacity, and school culture interact to shape digital innovation, but offers comparatively little in-depth, qualitative insight into how these dynamics unfold in a single subject area within a rural, resource-constrained school, the gap this study addresses.

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METHOD

Research Design and Site

This study used a qualitative approach with a case-study design, chosen because the research aimed to understand, in depth, the phenomenon of principal transformational leadership in promoting digital-based Biology learning innovation within its real, bounded organisational context. The case-study design allowed the process, interactions, and meanings surrounding this leadership to be explored holistically rather than measured through predetermined variables. The study was conducted over three months (January-March 2025) in a public senior secondary school located in a rural regency of East Nusa Tenggara Province, Indonesia, a site selected because it actively pursues quality-improvement programmes, shows a leadership dynamic directly relevant to the research focus, and offered accessible, comprehensive data.

Informants, Data Collection, and Analysis

Informants were selected through purposive sampling and comprised the school principal (the primary informant), the vice-principal for curriculum, Biology teachers, other teachers involved in digital learning development, and Grade XII science students as supporting informants. Data were collected through in-depth, semi-structured interviews focused on the four leadership dimensions and on the support given to technology use in Biology instruction; non-participant observation of classroom practice, available digital facilities, and teacher-student interaction; and documentation review covering the school's work plans, teacher-competence programmes, digitalisation policies, and training records. The researcher served as the primary instrument, supported by an interview guide, an observation sheet, and a documentation checklist. Data credibility was established through source triangulation (comparing accounts across the principal, teachers, and students), technique triangulation (comparing interview, observation, and documentation data), and member checking. Analysis followed an interactive model comprising data condensation, data display, and conclusion drawing and verification, conducted iteratively throughout data collection rather than only at its conclusion.

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RESULTS AND DISCUSSION

Findings are organised around the four dimensions of transformational leadership, followed by the supporting and inhibiting factors identified and the principal's strategies for addressing them.

Idealized Influence

The principal's idealized influence was expressed primarily through role-modelling. Rather than simply instructing teachers to use technology, the principal demonstrated personal commitment to school development by taking an active part in quality-improvement and innovation programmes, treating digital technology as a legitimate means of making instruction more engaging. This pattern echoes evidence that principals' digital transformational leadership shapes teachers' commitment and school effectiveness by first establishing the leader's own credibility as a change agent (Berkovich et al., 2025), consistent with findings that such leadership improves teachers' beliefs about, and skill with, technology (Schmitz et al., 2023). A principal who visibly values technology use gives teachers a concrete signal that experimentation with digital media in Biology instruction is legitimate and supported.

Inspirational Motivation

Beyond modelling, the principal sustained a shared vision for digital-based learning through repeated, explicit articulation of its purpose, framing technology integration as a gradual, achievable process. This stance was reinforced by concrete opportunities for teachers to pursue professional development and design more interactive instructional media, so that motivation was communicated through action as well as words, aligned with evidence that principals' digital leadership is associated with shifts in teachers' motivation and engagement when facing technology-driven change (Berkovich et al., 2025) and with findings that such leadership strengthens teachers' confidence in using technology pedagogically (Schmitz et al., 2023). A school culture that recognised effort, not only competence, helped reduce teachers' hesitancy to experiment despite uneven technology skills.

Intellectual Stimulation

Intellectual stimulation was evident in the principal's encouragement of teachers to think creatively about how digital tools could be used, rather than simply providing devices and

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expecting their use. Teachers were given room to experiment with digital media suited to their own content, and were encouraged to jointly resolve implementation problems rather than depend on the principal as the sole source of solutions, consistent with characterisations of transformational leadership as stimulating organisation members to become more innovative problem-solvers when integrating technology (Yufita & Sihotang, 2020). This mattered particularly for Biology instruction, where students must observe, analyse, and connect abstract concepts, so teachers were pushed to treat technology as a means of creating active, meaningful learning rather than merely a presentation aid, and to seek workable alternatives rather than abandon innovation when technical limitations arose.

Individualized Consideration

Because teachers' digital competence varied considerably, the principal did not apply a uniform approach but tailored support and coaching to each teacher's demonstrated ability and needs, consistent with evidence that teacher-level factors such as technology beliefs and technical and pedagogical skill are central to how far technology integration progresses (Schmitz et al., 2023). Teachers experiencing difficulty received targeted assistance, while more capable teachers were encouraged to develop and share their expertise, so the principal functioned as director and mentor at once. Teachers were also given room to express difficulties and ideas, and to exercise professional judgement in selecting digital media suited to their own content, an openness that built trust and reduced teachers' sense that technology adoption was an unsupported top-down demand.

Supporting and Inhibiting Factors, and the Principal's Response

Teachers' overall response to the principal's leadership was positive: digital tools including PowerPoint, YouTube, and instant-messaging platforms were incorporated into Biology instruction, and teachers reported that digital media made lessons more engaging, eased understanding of difficult material, and increased student participation. This uptake was not, however, uniform, reflecting the disparities in digital competence that individualized consideration was designed to address. Supporting factors identified were the principal's sustained commitment, teachers' own willingness to adopt new practices, and the availability of digital infrastructure, including computers, a smart screen or projector, and an internet connection, consistent with evidence that strategic leadership together with adequate technical

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and infrastructural conditions underpins successful school digital transformation (Navaridas-Nalda et al., 2020). The chief inhibiting factors were an unstable internet connection and students' limited mobile data quotas, alongside continuing gaps in some teachers' digital competence.

The principal addressed these barriers through a multidimensional strategy: expanding digital infrastructure; encouraging teachers' participation in training and experience-sharing to build technical and pedagogical skill; conducting supervision and mentoring focused on constructive feedback; embedding digital-learning needs into school planning so that innovation was institutionally, not only individually, supported; fostering peer collaboration so that more digitally capable teachers could mentor colleagues; and providing recognition to teachers who took the initiative to innovate. This pattern is consistent with a systematic review indicating that transformational leadership supports digital innovation through a combination of mechanisms rather than any single lever (Kausar et al., 2025), and with evidence that such leadership functions as a catalyst for digital-learning implementation (Handayani et al., 2025) and strengthens teachers' digital literacy more broadly (Juniarti et al., 2025). Overall, technology provision alone is insufficient: sustained, multidimensional transformational leadership is what converts available digital infrastructure into genuine, subject-specific pedagogical innovation, a conclusion with plausible relevance for other rural, resource-constrained school systems.

CONCLUSION

The principal's transformational leadership was enacted through all four dimensions: idealized influence, through visible personal commitment to technology-supported improvement; inspirational motivation, through sustained encouragement and a consistently articulated shared vision; intellectual stimulation, through encouragement of creative experimentation and joint problem-solving; and individualized consideration, through coaching tailored to each teacher's digital competence. Teachers responded positively despite uneven digital skills, incorporating digital tools into Biology instruction in ways that made learning more engaging. Supporting factors included the principal's commitment, teacher enthusiasm, and available infrastructure, while inhibiting factors centred on unstable internet connectivity, limited student data access, and residual competence gaps, which the principal addressed through training, mentoring, supervision, infrastructure development, and institutional planning. Overall, transformational leadership is affirmed as a critical enabler of digital innovation in science

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instruction, a pattern with plausible relevance to school systems worldwide facing similar resource constraints.

RECOMMENDATIONS

Principals are encouraged to sustain individualized coaching matched to teachers' digital competence, while expanding infrastructure and stabilising internet access. Teachers are encouraged to keep building digital competence and exercise creativity in selecting media suited to Biology content. Schools and authorities should sustain investment in digital facilities and training, and institutionalise peer-collaboration so innovation does not depend solely on individual initiative. Future research should extend this case-study approach to other subjects and school levels, combining qualitative inquiry with quantitative measures across larger samples.

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