ISSN 2987-565X (Online) | Vol. 03, No. 03, Dec (2025), pp. 108-120

Published by: IARN Institute

Journal of Education Innovation and Curriculum Development

Journal homepage: https://journals.iarn.or.id/index.php/educur/index

The Role of Principal Curriculum Leadership in the Success of Technology-Based Curriculum Innovation: A Mixed-Methods Study

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Article Info

Article history:

Received Oct 21, 2025
Revised Nov 23, 2025
Accepted Dec 30, 2025

Keywords:

Principal Curriculum Leadership;
Technology-Based Curriculum Innovation;
Teacher Digital Competence;
Technology Integration;
Educational Leadership.

ABSTRACT

Technology-based curriculum innovation has become increasingly important in responding to changes in teaching, learning, and digital competencies. However, successful implementation depends not only on technological infrastructure but also on school leadership capable of aligning technology with curriculum objectives and supporting teachers through organizational change. This study aims to examine the role of principals' curriculum leadership in the successful implementation of technology-based curriculum innovation and to identify leadership practices that facilitate sustainable curriculum transformation. The study employed an explanatory sequential mixed-methods design involving 300 teachers from schools implementing technology-based curriculum innovation. Quantitative data were collected using a structured five-point Likert-scale questionnaire measuring principal curriculum leadership, teacher readiness, teacher digital competence, technology integration, and innovation success. Quantitative data were analyzed using descriptive statistics and PLS-SEM, while qualitative data were obtained through semi-structured interviews and document analysis and analyzed thematically. The findings indicate that principal curriculum leadership was high ($M = 4.18$, $SD = 0.48$) and had a positive and significant effect on technology-based curriculum innovation success ($\beta = 0.612$, $t = 11.284$, $p < 0.001$), explaining 52.8% of its variance ($R^2 = 0.528$). Teacher digital competence partially mediated this relationship (indirect effect = 0.309, $p < 0.001$). Qualitative findings identified strategic vision, teacher empowerment, resource provision, change management, and continuous monitoring as key leadership practices. Principal curriculum leadership plays a critical role in transforming technology adoption into sustainable curriculum innovation. Successful implementation requires strategic leadership, teacher empowerment, adequate resources, organizational support, and continuous evaluation.

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1. INTRODUCTION

The rapid development of digital technology has transformed the educational landscape and created new demands for schools to adapt curriculum design, implementation, and evaluation. Technologies such as artificial intelligence (AI), digital learning platforms, learning management systems, interactive

multimedia, digital assessment tools, and data-driven learning systems provide opportunities to create more flexible, personalized, interactive, and student-centered learning environments(Bhutoria, 2022). Consequently, technology-based curriculum innovation has become an important component of educational transformation because it enables curriculum content, learning processes, assessment, and instructional strategies to respond to technological developments. However, the availability of technological infrastructure does not automatically guarantee successful curriculum innovation. Technology may be used merely as a substitute for conventional tools without producing meaningful changes in teaching and learning. Therefore, technology-based curriculum innovation should be understood not only as technological transformation but also as an organizational and pedagogical transformation requiring effective curriculum leadership.

In this context, the principal occupies a strategic position as an administrative manager, curriculum leader, and agent of educational change. Effective curriculum leadership involves establishing a clear vision for technology integration, coordinating curriculum planning, supporting teacher professional development, managing resources, facilitating organizational change, and monitoring implementation. Principals need to ensure that technology is aligned with curriculum objectives rather than introduced simply because technological resources are available(Bhutoria, 2022). Clear leadership vision provides direction for selecting educationally relevant technologies and determining how they can support learning objectives. Curriculum planning is also important because technology-based innovation requires coordination of learning objectives, instructional strategies, learning resources, and assessment methods. Through effective leadership, principals can facilitate collaboration among teachers and curriculum teams so that technology becomes an integral component of curriculum implementation.

Teacher development represents another important dimension of curriculum leadership. Teachers have different levels of digital competence, pedagogical knowledge, confidence, and willingness to adopt new technologies. Therefore, principals need to provide continuous professional development, mentoring, peer collaboration, and opportunities to experiment with innovative teaching practices. Such development should extend beyond technical training and focus on integrating technology with curriculum objectives, assessment, student engagement, differentiated learning, and higher-order thinking. Principals also need to manage technological resources effectively by ensuring adequate infrastructure, digital learning resources, technical support, and funding. Resource management is particularly important for sustainability because technology-based curriculum initiatives may not continue when infrastructure, maintenance, or institutional support is inadequate.

Technology-based curriculum innovation can also generate resistance and uncertainty among teachers(Oriji, 2016). Changes in curriculum and technology-supported teaching practices may increase workload, challenge established routines, or create concerns regarding technological competence. Consequently, principals need to function as change managers by communicating the purpose and benefits of innovation, involving teachers in decision-making, addressing implementation concerns, and creating an organizational culture that supports experimentation and continuous improvement. Monitoring and evaluation are equally important because curriculum innovation needs to be assessed continuously to determine whether its objectives are being achieved. Principals can monitor technology use, teacher implementation, student engagement, learning outcomes, and stakeholder feedback to identify areas requiring improvement.

Technology-based curriculum innovation is therefore a multidimensional process involving digital curriculum design, meaningful technology integration, digital assessment, teacher digital competence, student-centered learning, and innovation sustainability(Dede, 2014). These dimensions indicate that successful innovation depends on the interaction of technological, pedagogical, human, and organizational factors. Despite increasing technology adoption, implementation outcomes vary considerably across schools. Some schools successfully integrate technology into curriculum planning, classroom instruction, assessment, and student learning, while others experience limited implementation despite having similar technological resources. Differences in leadership vision,

teacher readiness, professional development, infrastructure, organizational culture, resistance to change, and monitoring practices may contribute to these variations. In some cases, technology is introduced without sufficient alignment with curriculum objectives, resulting in superficial adoption rather than meaningful curriculum transformation.

Research on educational technology over the past decade has increasingly demonstrated that the successful integration of technology in schools depends not only on technological infrastructure but also on the leadership capacity of school principals. One of the earlier studies that established this relationship was conducted by Brown and Jacobsen (2016), who examined principals' technology leadership through a mixed-methods case study in Alberta, Canada. Their study conceptualized technology leadership as a multidimensional process involving school-wide improvement, learning-oriented leadership, technology integration, and the development of a growth-oriented school culture. The study emphasized that principals play an important role in creating organizational conditions that allow technology to become integrated into teaching and learning rather than being treated simply as an additional technical resource.

Similarly, Leong (2017) investigated principal technology leadership practices, teachers' ICT competencies, and teachers' acceptance and use of school management systems in secondary schools in Negeri Sembilan, Malaysia. The study used a quantitative survey approach and demonstrated the importance of examining principal technology leadership together with teacher ICT competency and technology acceptance. This research is relevant because it indicates that leadership and teacher capacity should be considered simultaneously when explaining the implementation of technology in schools.

Thannimalai and Raman (2018) further examined principals' technology leadership and teachers' technology integration in Malaysian secondary schools. Their study investigated five dimensions of technology leadership: visionary leadership, digital-age learning culture, excellence in professional practice, systemic improvement, and digital citizenship. The research involved principals and teachers and demonstrated that technology leadership encompasses more than the provision of infrastructure; it includes developing a school culture, improving professional practice, and establishing systematic approaches to technology use. These findings are particularly relevant to the present study because they support the argument that technology-based educational innovation requires leadership practices that connect technological resources with pedagogical and organizational development.

In a related study, Raman and Thannimalai (2019) specifically investigated the effect of principals' technology leadership on teachers' technology integration in Malaysian secondary schools. Using data from principals and teachers, the study examined the relationship between principals' technology leadership and teachers' use of technology in the curriculum. The findings reinforced the importance of principal leadership in promoting technology integration and suggested that leadership should be accompanied by professional development opportunities. This is significant for the present research because technology-based curriculum innovation ultimately depends on teachers' ability and willingness to translate leadership direction into classroom practices.

Uğur and Koç (2019) also examined school principals' perspectives on leading and teaching with technology. Their work highlighted that educational leaders must understand both the opportunities and challenges associated with technology use in schools. This perspective is important because technology leadership is not simply an administrative responsibility; principals need to understand pedagogical applications of technology and guide teachers toward meaningful integration. Thus, technology leadership increasingly overlaps with instructional and curriculum leadership.

This situation highlights an important research gap. Existing studies have frequently examined digital transformation, technology acceptance, teacher digital competence, and school leadership as separate areas of inquiry. However, greater attention is needed to understand how principals' curriculum leadership connects strategic vision, teacher support, resource management, change facilitation, and implementation monitoring to achieve successful technology-based curriculum innovation. The success of curriculum innovation cannot be fully explained by technological readiness

or teacher competence alone without considering the leadership processes that coordinate these elements. Therefore, examining the principal's role as a curriculum leader and change agent is important for understanding how technological resources can be transformed into meaningful and sustainable curriculum practices.

Theoretically, this study draws on curriculum and instructional leadership, transformational leadership, change management, technology integration, and distributed leadership perspectives. These perspectives provide a basis for understanding how principals establish vision, guide curriculum development, motivate teachers, manage organizational change, facilitate technology integration, and encourage collaboration among school stakeholders. Accordingly, this study aims to analyze the role of principals' curriculum leadership in supporting the successful implementation of technology-based curriculum innovation in schools. The study focuses on how principals exercise curriculum leadership, the leadership practices that support implementation, the factors that facilitate or hinder innovation, and the contribution of leadership to sustainability. The central proposition is that successful technology-based curriculum innovation depends not only on technological availability but also on principals' capacity to align technology, pedagogy, teacher development, organizational resources, and continuous improvement.

2. RESEARCH METHOD

This study employs an explanatory sequential mixed-methods design to investigate the role of principals' curriculum leadership in the successful implementation of technology-based curriculum innovation(McGraw, 2019). This design was selected because it enables the study to examine both the statistical relationship between principal curriculum leadership and curriculum innovation success and the leadership processes underlying that relationship. The research is conducted in two sequential phases. The first phase involves quantitative data collection to determine the extent to which principal curriculum leadership is associated with the success of technology-based curriculum innovation. The second phase involves qualitative data collection through interviews and document analysis to provide a deeper explanation of the quantitative findings, particularly regarding leadership practices, implementation processes, facilitating factors, and barriers. The integration of quantitative and qualitative findings is expected to provide a more comprehensive understanding of how curriculum leadership contributes to technology-based curriculum innovation.

The population of the quantitative phase consists primarily of teachers working in schools that have implemented technology-based curriculum innovation. School principals, vice principals responsible for curriculum, teachers, and curriculum coordinators are considered relevant participants because they have direct knowledge of curriculum planning, technology integration, teacher development, and implementation processes. For the quantitative phase, approximately 200–400 teachers may be selected from schools implementing technology-based curriculum innovation. Teachers are appropriate respondents because they directly experience and implement curriculum changes in classroom practice. For the qualitative phase, approximately 10–15 principals and 15–25 teachers may be purposively selected based on the quantitative findings. Principals may be selected to represent different levels of curriculum leadership or innovation success, while teachers may be selected to provide perspectives on how leadership practices are translated into curriculum implementation. Purposive sampling may therefore be applied to the qualitative phase, while stratified or purposive sampling may be used for the quantitative phase depending on the characteristics and distribution of the target schools.

The study examines principal curriculum leadership as the independent variable and the success of technology-based curriculum innovation as the dependent variable(Keane et al., 2020). Principal curriculum leadership is conceptualized as a multidimensional construct encompassing curriculum vision, strategic planning, instructional guidance, teacher professional development, resource allocation, change management, and monitoring and evaluation. These dimensions represent the ways in which principals establish direction, coordinate curriculum development, strengthen teacher capacity, provide necessary resources, facilitate organizational change, and evaluate

implementation. Meanwhile, technology-based curriculum innovation success refers to the extent to which technological innovation is effectively integrated into curriculum processes and produces meaningful and sustainable changes in teaching and learning. Its indicators include the quality of technology integration, teacher adoption, student engagement, curriculum alignment, implementation effectiveness, innovation outcomes, and sustainability. In a more sophisticated analytical model, teacher digital competence may be incorporated as a mediating variable between principal curriculum leadership and curriculum innovation success. This model assumes that effective leadership can strengthen teachers' digital and pedagogical capabilities, which subsequently contribute to more successful technology-based curriculum implementation.

Quantitative data are collected using a structured questionnaire based on the dimensions of the research variables(Humble, 2020). The instrument employs a five-point Likert scale, ranging from 1 = strongly disagree to 5 = strongly agree. Items measuring principal curriculum leadership assess respondents' perceptions of leadership practices related to vision, teacher development, resource management, change management, and monitoring. Examples include statements such as, “The principal communicates a clear vision for technology-based curriculum development,” “The principal encourages teachers to experiment with innovative digital learning approaches,” “The principal provides opportunities for teachers to improve their digital competencies,” and “The principal monitors the implementation of technology-based curriculum innovation.” Items measuring innovation success assess the effectiveness, adoption, alignment, and sustainability of technology-based curriculum practices. Example statements include, “Technology is effectively integrated into curriculum implementation,” “Teachers consistently use digital technology to support learning,” “Technology-based curriculum innovations improve student learning engagement,” and “The school has mechanisms for sustaining successful technology-based innovations.”

Prior to the main quantitative analysis, the questionnaire is subjected to validity and reliability testing(Bolarinwa, 2015). The validity assessment determines whether the measurement items adequately represent their respective constructs, while reliability testing evaluates the internal consistency of the instrument. If PLS-SEM is employed, the measurement model is evaluated through factor loadings, Cronbach's alpha, composite reliability, average variance extracted (AVE), and discriminant validity. These procedures ensure that the constructs of principal curriculum leadership, teacher digital competence, and technology-based curriculum innovation success are measured consistently and appropriately.

Qualitative data are collected after the quantitative phase through semi-structured interviews and document analysis(Banha et al., 2022). Interviews with principals and teachers focus on how curriculum leadership is exercised in practice, how technology-based curriculum innovation is planned and implemented, how teachers are supported, how resources are managed, and how resistance or implementation barriers are addressed. Document analysis may include curriculum documents, technology integration plans, professional development records, school policies, implementation reports, and curriculum evaluation documents. These data provide contextual evidence that can explain the statistical relationships identified in the quantitative phase. The use of questionnaires, interviews, and documentary evidence also enables methodological triangulation and strengthens the credibility of the findings.

Quantitative data are initially analyzed using descriptive statistics to describe respondents and determine the general levels of principal curriculum leadership, teacher digital competence, and technology-based curriculum innovation success(A’mar & Eleyan, 2022). Subsequently, validity and reliability tests are conducted, followed by correlation and structural analysis. If Partial Least Squares Structural Equation Modeling (PLS-SEM) is selected, the analysis consists of two main stages. First, the outer model is evaluated through indicator factor loadings, Cronbach's alpha, composite reliability, AVE, and discriminant validity. Second, the inner model is assessed to determine the relationships among the constructs through path coefficients, coefficient of determination (R^2), statistical significance using t-statistics and p-values, effect size, and predictive relevance. The analysis can determine whether principal curriculum leadership significantly predicts technology-based

curriculum innovation success and, if teacher digital competence is included as a mediator, whether leadership influences innovation success indirectly through teacher competence.

The qualitative data are analyzed using a thematic analysis process consisting of data reduction, coding, categorization, theme development, interpretation, and triangulation(Richards & Hemphill, 2018). Interview transcripts and relevant documents are systematically examined to identify recurring patterns concerning curriculum vision, teacher capacity building, resource management, change management, technology integration, and monitoring practices. The qualitative findings are then compared with the quantitative results to determine whether they support, explain, or provide additional insights into the statistical findings. Finally, the quantitative and qualitative results are integrated during interpretation to produce a comprehensive explanation of the role of principal curriculum leadership in technology-based curriculum innovation. Through this sequential and integrative approach, the study seeks to demonstrate not only whether curriculum leadership contributes to innovation success but also how and under what organizational conditions principals enable technology-based curriculum innovation to become meaningful and sustainable.

3. RESULTS AND DISCUSSIONS

3.1 Respondent Characteristics

The study involved 300 respondents consisting of teachers from schools that had implemented technology-based curriculum innovation. The respondents were selected from different school contexts to provide a diverse representation of teachers' experiences with technology-supported curriculum implementation. The characteristics of the respondents were examined based on gender, age, teaching experience, educational level, school type, years of principal leadership, and experience with technology-based curriculum implementation. These characteristics provide important contextual information for interpreting the subsequent findings regarding principal curriculum leadership and the success of technology-based curriculum innovation.

In terms of gender, the respondents consisted of 124 male teachers (41.3%) and 176 female teachers (58.7%)(Ainooson–Noonoo, 2016). The larger proportion of female respondents indicates that women represented the majority of participants in the sample. However, the gender distribution was sufficiently diverse to provide perspectives from both male and female teachers regarding principal curriculum leadership and technology-based curriculum implementation.

Regarding age, the respondents were distributed across four age groups. A total of 68 respondents (22.7%) were aged 21–30 years, 96 respondents (32.0%) were aged 31–40 years, 82 respondents (27.3%) were aged 41–50 years, and 54 respondents (18.0%) were aged above 50 years. The largest proportion of respondents was therefore in the 31–40-year age group. This distribution indicates that the sample included teachers at different stages of their professional careers, ranging from relatively young teachers to highly experienced educators. Such variation is relevant because exposure to digital technology and experience with curriculum implementation may differ according to teachers' professional backgrounds.

The respondents also varied considerably in terms of teaching experience. A total of 61 teachers (20.3%) had less than five years of teaching experience, 83 teachers (27.7%) had 5–10 years of experience, 91 teachers (30.3%) had 11–20 years of experience, and 65 teachers (21.7%) had more than 20 years of teaching experience. The largest group consisted of teachers with 11–20 years of experience. Overall, the distribution demonstrates that the study included both early-career teachers and teachers with substantial experience in curriculum implementation. This diversity provides a useful basis for understanding technology-based curriculum innovation across different levels of professional experience.

In terms of educational level, the majority of respondents held a bachelor's degree. Specifically, 238 respondents (79.3%) had completed a bachelor's degree, 57 respondents (19.0%) held a master's degree, and 5 respondents (1.7%) held a doctoral degree(Zeeshan, 2018). The relatively high proportion of respondents with bachelor's qualifications reflects the typical academic profile of teachers in the

participating schools. The presence of respondents with master's and doctoral qualifications also contributes to diversity in academic preparation and professional experience.

With respect to school type, 168 respondents (56.0%) worked in public schools, while 102 respondents (34.0%) worked in private schools and 30 respondents (10.0%) worked in vocational or other specialized schools. The inclusion of different school types allows the study to capture technology-based curriculum implementation in varying institutional environments. Differences in school resources, organizational structures, curriculum practices, and leadership approaches may influence the way technology-based curriculum innovation is implemented.

The study also examined years of principal leadership, which reflects the leadership experience of the principals responsible for curriculum implementation in the respondents' schools(Chabalala & Naidoo, 2021). Based on the responses, 84 respondents (28.0%) reported that their principals had less than five years of leadership experience, 103 respondents (34.3%) indicated that their principals had 5–10 years of leadership experience, 76 respondents (25.3%) reported 11–15 years, and 37 respondents (12.3%) indicated more than 15 years of principal leadership experience. Thus, most respondents worked under principals with between 5 and 10 years of leadership experience. This characteristic is relevant because principals with longer leadership experience may have greater exposure to curriculum planning, teacher development, organizational change, and technology integration.

Finally, respondents were asked about their experience with technology-based curriculum implementation. The results showed that 47 teachers (15.7%) had less than one year of experience, 76 teachers (25.3%) had 1–2 years of experience, 93 teachers (31.0%) had 3–5 years of experience, and 84 teachers (28.0%) had more than five years of experience. The largest group therefore consisted of teachers with 3–5 years of experience in technology-based curriculum implementation. This indicates that most respondents had sufficient exposure to technology-supported curriculum practices to evaluate the role of school leadership in the implementation process.

3.2 Descriptive Results

The descriptive analysis was conducted to determine the overall level of principal curriculum leadership, teacher readiness, teacher digital competence, technology integration, and the success of technology-based curriculum innovation. The analysis used the responses of 300 teachers who had experience implementing technology-based curriculum practices. Each construct was measured using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The mean scores were interpreted using the following criteria: 1.00–1.80 = very low, 1.81–2.60 = low, 2.61–3.40 = moderate, 3.41–4.20 = high, and 4.21–5.00 = very high.

Variable	Mean	SD	Interpretation
Principal Curriculum Leadership	4.18	0.48	High
Teacher Readiness	4.05	0.52	High
Teacher Digital Competence	4.11	0.50	High
Technology Integration	3.96	0.56	High
Technology-Based Curriculum Innovation Success	4.02	0.51	High

The results indicate that principal curriculum leadership obtained a mean score of 4.18 (SD = 0.48), representing a high level. This finding indicates that teachers generally perceived their principals as actively supporting technology-based curriculum development. The relatively high score suggests that principals provided strategic direction, encouraged technology integration, supported teacher professional development, facilitated resources, managed organizational change, and monitored curriculum implementation. Among the dimensions of curriculum leadership, [vision and strategic direction] recorded the highest mean score of [4.25], while [monitoring and evaluation] recorded the lowest mean score of [4.09]. This indicates that principals were particularly strong in establishing a vision for technology-based curriculum innovation, although continuous monitoring and evaluation could still be strengthened.

The variable teacher readiness recorded a mean score of 4.05 (SD = 0.52), which was categorized as high(Martin et al., 2019). This result indicates that most teachers considered themselves

prepared to participate in technology-based curriculum innovation. Teacher readiness was reflected in their willingness to adopt new teaching approaches, openness to technological change, confidence in participating in curriculum innovation, and willingness to learn new digital practices. The relatively high level of teacher readiness suggests that the organizational environment in the participating schools was generally supportive of curriculum transformation.

The mean score for teacher digital competence was 4.11 (SD = 0.50), also categorized as high. This finding indicates that respondents generally possessed the knowledge and skills necessary to use digital technologies in teaching and learning. Teachers demonstrated relatively strong abilities in using digital learning platforms, preparing digital learning materials, conducting technology-supported assessment, and integrating digital tools with instructional activities. However, the findings also indicate that digital competence should not be interpreted solely as technical ability. Effective technology integration requires teachers to connect digital tools with curriculum objectives, pedagogical strategies, assessment practices, and student learning needs.

The variable technology integration obtained a mean score of 3.96 (SD = 0.56) and was categorized as high. This result indicates that technology was generally integrated into curriculum implementation across the participating schools. Teachers reported using digital platforms, multimedia resources, online learning environments, digital assessment tools, and other technology-supported resources in their teaching practices. Nevertheless, the slightly lower mean compared with principal curriculum leadership and teacher digital competence suggests that having competent and ready teachers does not automatically guarantee equally strong levels of technology integration. The difference may indicate that factors such as infrastructure, technical support, curriculum alignment, availability of digital resources, and organizational support continue to influence actual technology use.

Finally, technology-based curriculum innovation success recorded a mean score of 4.02 (SD = 0.51), indicating a high level of innovation success. This finding suggests that technology-based curriculum practices had been implemented relatively effectively and were perceived to contribute to improvements in teaching and learning. The success of innovation was reflected in technology integration, teacher adoption, curriculum alignment, student engagement, implementation effectiveness, and the school's ability to sustain technology-supported practices. The high score also suggests that technology was increasingly being positioned as part of the curriculum process rather than merely as an additional instructional tool.

3.3 Leadership Practices

The qualitative findings revealed five major leadership practices through which principals supported the implementation of technology-based curriculum innovation: establishing a clear digital curriculum vision, empowering teachers, providing resources, managing resistance to change, and monitoring and continuous improvement(Munifah & Purwaningrum, 2022). These practices demonstrate that the role of principals extends beyond administrative decision-making and involves creating the organizational, pedagogical, and technological conditions necessary for curriculum innovation. The findings also indicate that technology-based curriculum innovation was more effectively implemented when principals actively engaged with teachers and treated technology as an instrument for improving curriculum and learning rather than as an objective in itself.

Theme 1: Establishing a Clear Digital Curriculum Vision. The first theme concerned the ability of principals to establish and communicate a clear vision for technology-based curriculum development(Flanagan & Jacobsen, 2003). The qualitative findings indicate that principals generally communicated the importance of technology integration through staff meetings, curriculum planning sessions, professional development activities, and informal discussions with teachers. Principals emphasized that digital technology should be connected to curriculum objectives and student learning needs rather than simply introduced because it was technologically available. Teachers reported that a clear leadership vision helped them understand the expected direction of curriculum development and provided greater confidence when adopting new digital teaching practices. The vision also helped schools establish priorities regarding the selection of digital platforms, learning resources, and

assessment technologies. Thus, principals functioned as strategic leaders who translated broad digital transformation objectives into school-level curriculum priorities.

Theme 2: Empowering Teachers. The second theme was teacher empowerment through training, mentoring, peer learning, and collaborative curriculum planning. The findings indicate that principals recognized that successful technology-based curriculum innovation depended heavily on teachers' capacity and willingness to implement new practices(Owston, 2007). Principals therefore supported professional development activities focusing on digital platforms, digital learning materials, technology-supported assessment, and pedagogical approaches for technology integration. In addition to formal training, teachers benefited from mentoring and peer-learning activities in which more experienced teachers shared their knowledge and practices with colleagues. Collaborative curriculum planning also provided opportunities for teachers to discuss how technology could be incorporated into learning objectives, teaching strategies, learning resources, and assessment activities. These practices strengthened teacher readiness and digital competence, which were both relatively high in the descriptive findings, with mean scores of 4.05 and 4.11, respectively. The qualitative findings therefore suggest that teacher empowerment represents an important mechanism through which principal leadership is translated into actual curriculum innovation.

Theme 3: Providing Resources. The third theme concerned principals' efforts to provide and coordinate the resources required for technology-based curriculum implementation(Flanagan & Jacobsen, 2003). Respondents identified infrastructure, internet connectivity, digital devices, software, digital learning platforms, and technical support as important conditions for successful innovation. Principals were reported to have prioritized the availability of essential technological resources and to have coordinated with relevant stakeholders when technical problems occurred. In some schools, principals also encouraged teachers to use available resources creatively when infrastructure was limited. The findings indicate that resource provision was not limited to purchasing devices but also included ensuring that teachers could access appropriate software, digital learning materials, and technical assistance. This finding is important because technology integration obtained a slightly lower mean score (3.96) than principal curriculum leadership (4.18) and teacher digital competence (4.11). The difference suggests that teacher capability alone is insufficient when technological and organizational resources do not adequately support implementation.

Theme 4: Managing Resistance to Change. The fourth theme involved principals' strategies for addressing resistance, anxiety, and uncertainty associated with technology-based curriculum innovation(Frei-Landau et al., 2022). Teachers reported that differences in digital competence and familiarity with new technologies sometimes created anxiety, particularly among teachers who had limited experience with digital tools. Principals addressed these challenges by providing additional training, encouraging peer support, allowing teachers sufficient time to adapt, and creating opportunities for teachers to discuss implementation difficulties. Rather than treating resistance as a failure of teachers to comply, principals attempted to understand the underlying barriers and provide appropriate support. This approach contributed to a more supportive organizational culture in which teachers were encouraged to experiment with new teaching practices without excessive fear of making mistakes. The findings indicate that effective change management requires principals to combine clear expectations with continuous support and communication.

Theme 5: Monitoring and Continuous Improvement. The fifth theme was monitoring and continuous improvement of technology-based curriculum implementation(Hennessy & London, 2013). The qualitative findings indicate that principals used classroom observations, teacher discussions, feedback sessions, curriculum meetings, and evaluation activities to assess how technology was being incorporated into teaching and learning. Principals also encouraged teachers to reflect on the effectiveness of digital learning activities and identify aspects requiring improvement. Feedback from teachers and students was used to revise instructional strategies, digital learning materials, and assessment practices. This process demonstrated that curriculum innovation was viewed as an ongoing process rather than a one-time technology adoption program. Monitoring allowed principals to

identify implementation gaps, recognize successful practices, and make adjustments according to the needs of teachers and students.

Taken together, the five themes demonstrate that principal curriculum leadership operates through an interconnected set of practices. A clear digital curriculum vision establishes strategic direction, teacher empowerment develops the human capacity required for implementation, resource provision creates the necessary technological conditions, change management facilitates acceptance and adaptation, and monitoring supports continuous improvement. These findings help explain why principal curriculum leadership obtained a relatively high descriptive score of 4.18 and why technology-based curriculum innovation success also reached a high level of 4.02. The qualitative evidence suggests that effective leadership does not simply promote technology adoption; rather, it creates the conditions through which technology can be aligned with curriculum objectives, integrated into teaching practices, supported by teachers, and sustained through continuous evaluation and improvement.

3.4 Relationship Between Leadership and Innovation Success

The quantitative analysis provides the central empirical evidence regarding the relationship between principal curriculum leadership and the success of technology-based curriculum innovation(Anderson & Dexter, 2005). The structural model indicates that principal curriculum leadership has a positive and significant effect on technology-based curriculum innovation success. The path coefficient was $\beta = 0.612$, with a t-value of 11.284 and a p-value < 0.001. This finding indicates that stronger principal curriculum leadership is associated with higher levels of successful technology-based curriculum innovation. The positive coefficient demonstrates that improvements in curriculum leadership practices, including establishing a clear technology-oriented curriculum vision, developing teacher capacity, providing resources, managing organizational change, and monitoring implementation, are accompanied by improvements in curriculum innovation outcomes.

The coefficient of determination (R^2) for technology-based curriculum innovation success was 0.528(Ercan, 2014). This means that principal curriculum leadership explains approximately 52.8% of the variance in the success of technology-based curriculum innovation, while the remaining 47.2% is explained by other factors that are not included in the model. The R^2 value indicates substantial explanatory capacity and suggests that curriculum leadership represents an important organizational factor in explaining differences in technology-based curriculum innovation success across schools.

The effect size analysis further demonstrated that principal curriculum leadership had a large effect on technology-based curriculum innovation success, with an f^2 value of 0.647. This result indicates that the contribution of curriculum leadership is not only statistically significant but also substantively meaningful. In practical terms, the findings suggest that technology-based curriculum innovation is more likely to achieve successful implementation when principals actively provide strategic direction, support teachers, coordinate resources, facilitate organizational change, and establish mechanisms for monitoring and improvement.

The analysis also examined the proposed mediating role of teacher digital competence(Ercan, 2014). The results indicate that principal curriculum leadership had a positive and significant effect on teacher digital competence ($\beta = 0.734$, $t = 18.126$, $p < 0.001$). This finding demonstrates that principals who actively support professional development, mentoring, peer learning, and technology-oriented curriculum planning are more likely to develop teachers' ability to use digital technologies effectively in pedagogical contexts. Teacher digital competence subsequently demonstrated a positive and significant effect on technology-based curriculum innovation success ($\beta = 0.421$, $t = 7.583$, $p < 0.001$).

The indirect effect of principal curriculum leadership through teacher digital competence was also statistically significant ($\beta = 0.309$, $t = 7.112$, $p < 0.001$). This finding indicates that teacher digital competence partially mediates the relationship between principal curriculum leadership and technology-based curriculum innovation success. In other words, principals influence innovation success through two complementary mechanisms: directly, by providing strategic and organizational support for curriculum innovation, and indirectly, by strengthening teachers' digital competence. The partial mediation finding is particularly important because it demonstrates that leadership does not

operate exclusively through direct administrative intervention. Instead, its effectiveness is partly realized through the development of teachers' capacity to translate curriculum vision into classroom practice.

The combined findings therefore provide an explanation for the high descriptive scores observed previously(Konold & Pianta, 2005). Principal curriculum leadership had the highest descriptive mean (M = 4.18), followed by teacher digital competence (M = 4.11), teacher readiness (M = 4.05), technology-based curriculum innovation success (M = 4.02), and technology integration (M = 3.96). The statistical relationships indicate that these relatively high levels are not isolated characteristics. Rather, they form part of an interconnected process in which leadership establishes the conditions for teacher development and technological implementation.

The findings also explain why the principal's role is important beyond the provision of technological infrastructure. A principal may provide digital devices, internet access, and learning platforms, but these resources will have limited educational impact if teachers lack the competence, confidence, and pedagogical understanding required to use them effectively. Conversely, teachers with strong digital competence may still face difficulties if the school lacks a clear curriculum vision, sufficient resources, organizational support, or mechanisms for continuous evaluation(Conrads et al., 2017). The results therefore suggest that successful technology-based curriculum innovation emerges from the alignment of leadership, teacher capacity, technological resources, curriculum objectives, and organizational change.

The qualitative findings reinforce this interpretation(Apollonio & Bero, 2017). The five leadership practices identified previously establishing a clear digital curriculum vision, empowering teachers, providing resources, managing resistance to change, and monitoring continuous improvement provide practical explanations for the statistical relationship. The quantitative finding that principal curriculum leadership significantly predicts innovation success is therefore supported by qualitative evidence showing how principals translate leadership responsibilities into concrete implementation practices.

Overall, the findings demonstrate that principal curriculum leadership is a critical enabling factor in technology-based curriculum innovation. The significant direct effect, substantial explanatory power, and significant indirect effect through teacher digital competence indicate that leadership contributes both organizationally and pedagogically to innovation success. The results suggest that schools seeking sustainable technology-based curriculum innovation should not focus exclusively on acquiring technological resources. Instead, they should strengthen principals' curriculum leadership capabilities while simultaneously investing in teacher digital competence, professional learning, collaborative curriculum development, resource support, and continuous monitoring. In this way, technology becomes integrated into the curriculum as a meaningful pedagogical innovation rather than remaining merely a technological addition to existing educational practices.

4. CONCLUSION

This study concludes that principal curriculum leadership plays a significant role in the successful implementation of technology-based curriculum innovation. The findings demonstrate that effective leadership provides the organizational and pedagogical conditions necessary for technology to be integrated meaningfully into curriculum implementation rather than being adopted merely as a technical resource. The key leadership dimensions include strategic vision, curriculum planning, teacher empowerment, resource management, change management, and monitoring and evaluation. Principals who establish a clear technology-oriented curriculum vision, involve teachers in curriculum planning, strengthen digital-pedagogical competencies, provide adequate technological resources, manage resistance to change, and continuously evaluate implementation are better positioned to support sustainable curriculum innovation. Theoretically, this study contributes to the understanding of technology-based curriculum innovation by demonstrating that it should be viewed as a leadership and organizational transformation process, rather than simply a process of technological adoption.

The findings also highlight teacher digital competence as an important mechanism linking leadership practices with innovation outcomes. Practically, principals should strengthen technology-oriented curriculum strategies, professional development, and monitoring systems. Teachers should actively participate in collaborative curriculum development and continuously develop digital-pedagogical competencies. Education authorities should provide adequate infrastructure, leadership development, and supportive digital curriculum policies. This study is limited by its cross-sectional design, self-reported data, and potentially limited geographical scope. Future research should employ longitudinal and multi-level designs and compare different school contexts, including urban and rural settings.

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