Pak. j. life soc. Sci. (2025), 23(1): 3117-3128 E-ISSN: 2221-7630;P-ISSN: 1727-4915

Pakistan Journal of Life and Social Sciences
www.pjlss.edu.pk

https://doi.org/10.57239/PJLSS-2025-23.1.00247

RESEARCH ARTICLE

Dynamics of Principals' Complexity Leadership towards Teachers' Digital Transformation in High Schools

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ARTICLE INFO

Received: Nov 10, 2024

Accepted: Jan 15, 2025

Keywords

Principal

Complexity leadership

Teacher digital transformation

Senior high school

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ABSTRACT

The rapid development of technology requires teachers to be proficient in digital. In this case, the leadership of the principal is crucial to influence them in mastering digital-based learning. This study aims to investigate the effect of complexity leadership on teachers' digital competence and to find out the principal's strategy to improve it. Mixed method with explanatory design is used to obtain comprehensive results. A survey was conducted on 291 teachers to obtain quantitative data while interviews were used to obtain qualitative data. Furthermore, data was processed with SPSS. The results of the study showed that the principal's complexity leadership has a positive influence on teachers' digital competence by 28.30%. If the implementation of the principal's complexity leadership model is carried out consistently, the digital competence of teachers will increase. Indicators of this leadership model such as administrative leadership, adaptive leadership, shared leadership and leader behavior are strategies implemented by principals in improving teachers' digital competence in schools. These findings provide valuable contributions to the development of science, especially in the field of educational leadership, as well as a rational description of principals who apply the complexity leadership model.

INTRODUCTION

Teachers in the digital age are dealing with rapid changes. Teachers must have exceptional digital competency in order to stay up with pupils' diverse qualities (Caena & Redecker, 2019; Starkey, 2020). The goal is to make the teaching and learning process more effective and efficient by allowing them to teach more creatively with technology. Improving digital pedagogical skills is a sign of competency (Fernández-Batanero et al., 2022; Howard et al., 2021). Teachers must be able to not only develop engaging learning media, but also use the internet for learning materials and social media for learning. This is very similar to the competence of 21st century teachers, which is to have high digital abilities and literacy.

Teachers' digital competency is strongly linked to their ability to use information and communication technology. According to Mishra & Koehler (2006), the use of suitable technology in learning is a cooperation of pedagogy (P), content (C), and technology (T), which results in intersections and areas of concentration that demonstrate that teachers can develop input from classroom learning. Teachers must be able to use technology to enhance classroom learning for pupils. Because using digital technology in the classroom can boost creativity, motivation, and student engagement (Tang

et al., 2022). Seufert & Scheffler (2018) emphasize this by stating that the use of digital technology can help students learn employment skills such as communication skills, creativity, and the capacity to work in teams. In accordance with digital competence, teachers are no longer the sole source of learning, as students can study and master topics that teachers have not or have not mastered.

According to the European Commission in the digital era, teachers must adhere to the pillars of digital capabilities which include aspects (1) Professional engagement, the use of information technology in this area is not only as a learning support but also as a professional liaison with students, parents and groups who have the same interests. (2) Digital devices, teachers can take advantage of the diversity of technology products that provide learning effectiveness and efficiency. (3) Learning and teaching, teaching and learning activities can be interpreted more broadly when viewed from the presence of technology, its presence can make teachers free to develop learning formats, bridge collective interactions or personal guidance to students more freely. (4) Assessment, the role of technology in learning assessment can be used as a maker or monitoring device and as a continuous teaching strategy. (5) Student empowerment, technology can be adjusted to the learning needs of the students themselves so that teachers can also provide learning freedom without reducing the existence of the teacher through the selection of learning tools or media, measuring learning outcomes, empowering students through technology and fostering digitalization skills in students (Rubach & Lazarides, 2021).

In 2020, the Indonesian Child Protection Commission and the Indonesian Teachers' Union Federation conducted distance learning research involving 602 teachers from 14 provinces, revealing that only 8% of teachers understood the use of gadgets/cellphones in learning, while 53% of teachers in schools remain focused on basic student competencies without changing learning patterns or targets during the pandemic. These findings reveal that Indonesian teachers are still hesitant to use digital infrastructure to assist learning in schools and have failed to make learning engaging and enjoyable in response to student requirements. This implementation is still far from what was conveyed: professional teachers who educate without isolating students from the latest developments such as the internet and social media, but instead use technology features and platforms to support innovation and the educational function of teachers in order to achieve learning objectives. According to a survey conducted by the Center for Data on Technology and Information on Education and Culture, 60% of teachers are unable to use technology in the classroom, with the majority falling into the category of technological stutters. This discovery is undoubtedly a complex topic, as the heart of education, namely instructors, lack of competency. It is evident that instructors' lack of digital competency has a direct impact on teachers, including the ongoing learning process. According to a poll conducted by the Ministry of Education and Culture's Technology and Communication Center, only 40% of non-information and communication technology (ICT) teachers are prepared to use technology. As a result, technological mastery is achieved.

Principals who display visionary leadership can encourage instructors to use digital tools and approaches. Effective leadership aimed at making the right and intelligent judgments, as well as encouraging leaders to have a broad and deep viewpoint, communicate and interact, and have high creativity and innovation, is critical to meeting today's difficulties (Lestari et al., 2024). Complexity leadership is an alternative approach for organizations to survive in an environment that tends to be volatile, unpredictable, competitive, and information technology-based (Uhl-Bien et al., 2007). Complexity leadership views organizations as dynamic and complex systems of social interactions, emphasizing the role of interactions in driving change, innovation, and evolution in organizations (Gibbs et al., 2019). The complexity leadership model creates adaptability, learning, and innovation in organizations (Murray, 2017).

Uhl-Bien & Arena (2017) in their research stated that complexity leadership can strengthen employee involvement in the decision-making process through adaptive and responsive strategies to change. In fact, Nooteboom & Termeer (2013) emphasized that: (1) complex leadership can strengthen the adaptability and responsiveness of government. (2) complex leadership presents effective solutions for the benefit of society. (3) complex leadership can direct organizations towards

sustainable and results-oriented development. Tsai et al (2019) conducted an analysis of 21st century learning in British higher education institutions using complex leadership theory. The study explained that complexity leadership facilitates adaptation to technological change in building learning innovation. Dawson et al (2018) reinforced by saying that complexity leadership can form a culture that supports innovation, shared learning, and adaptation to educational change.

Research on the complexity leadership model on teachers' digital competence is very rare. As a practical contribution in the future, this study provides a rational description to principals who apply this leadership model . Based on these reasons, the research question is how much influence does complexity leadership have on teachers' digital competence and what are the principals' strategies to improve teachers' digital competence?

THEORETICAL FRAMEWORK

Complexity Leadership of Principals

Complexity leadership emerged from the development and maturation of theories such as transformational, contingent, and distributed leadership (Hunt & Dodge, 2000). Complexity leadership theorists believe that existing theories are not well positioned to address the challenges that leaders face in increasingly complex organizations characterized by complex regulations. Complexity leadership emerged as a response to the increasing complexity of organizations (Lichtenstein et al., 2006).

According to Uhl-Bien et al (2020), complexity leadership is a framework for understanding how to enable people and organizations for adaptability. It draws from complex adaptive systems (CAS) theory in complexity science to show how systems can be more adaptive in the face of complexity. Schophuizen et al. (2023) convey that complexity leadership means giving room for change and innovation, and harnessing the results of the natural interactions that take place in organizations. Despite the complexity of leadership theory is a systems theory, the leadership component itself still plays an important role: whenever an event takes place and people react and adapt to it, innovation and creativity can take place. Donkor & Zhou (2019) explain that complexity leadership seeks to integrate the dynamics of complex adaptive systems with traditional bureaucratic hierarchies within organizations. The goal is to explain how informal organizational dynamics function effectively and to describe how valuable adaptive functions can be promoted to improve operations.

Complex problems in organizations and their subsystems need to be addressed with complex responses and complexity leadership approaches. This leadership seeks to minimize chaos and bring order to the organization and its subsystems (Lichtenstein & Plowman, 2009; Marion & Uhl-Bien, 2001). Complexity leadership is seen as a means for leaders to encourage experimentation, establish routines, create appropriate chains of responsibility, encourage a learning culture, and recognize accountability among agents in the organization (Hazy & Uhl-Bien, 2015).

According to Clarke (2013), the four dimensions in the complexity leadership model consist of (1) network conditions, (2) shared leadership, (3) organizational learning, and (4) leader behavior. According to Baltaci & Balcı (2017), the main characteristics of complexity leadership include administrative, adaptive, and action. In organizations, administrative and adaptive leadership interact and can be supportive or contradictory. Administrative leadership can function in harmony with adaptive leadership or inhibit it through overly authoritarian or bureaucratic control structures. Conversely, adaptive leadership can reinforce the strategic needs of administrative leadership, counteract administrative leadership, or act independently (Uhl-Bien et al., 2007). Complexity leadership plays a role in transforming ideas into systems that generate innovation through three aspects such as operational leadership, entrepreneurial leadership, and supporting leadership (Uhl-Bien & Arena, 2017).

Teacher Digital Competence (TDC)

Teacher Digital Competence (TDC) framework guides policy revision and professional development , empowering teachers for future classrooms by technologies such as artificial intelligence (AI) and

metaverse (Chiu et al., 2024). Which is to use digital technology in a way that ensures student teachers graduate from teacher education (TE) with the professional digital competence (PDC) needed for their future working lives in a digitalised school (Lindfors et al., 2021).

The importance of digital competence as one of the challenges facing teachers today. Digital competence has gained a strong prominence in the educational context, becoming one of the key competencies that teachers must master in today's society (Basilotta-Gómez-Pablos et al., 2022; Guillén-Gámez et al., 2020). Information and Communication Technologies have played a substantial role in improving both the quality of life for people (Fernández-Batanero et al., 2022; Haseeb et al., 2019). Digital competency is a multifaceted learning competency, which means that each part is linked to the next. Not only in technical learning, but also in learning components so that the integration of information technology is holistic (Oberländer et al., 2020).

The concept of teachers' professional digital competence still appears to be ambiguous and elusive. Falloon (2020) expanded the TPACK framework to include personal-ethic and personal-professional competencies, addressing ethical, safe, and productive functioning in diverse, digital environments for a new TDC framework. The two new sets of personal-competencies are very important to the use of AI and metaverse in education. Skantz-Åberg et al. (2022) could distinguish seven recurring aspects of teachers' professional digital competence; 1) technological competence, 2) content knowledge, 3) attitudes to technology use, 4) pedagogical competence, 5) cultural awareness, 6) critical approach and 7) professional engagement, with the technological and pedagogical competences as the most prominent.

In addition to technical skills, teachers must be able to effectively integrate digital resources into their teaching practices. Designing interactive and engaging learning experiences using technology can improve student comprehension and involvement (Diachuk, 2024; Falloon, 2020). They must also control the social dynamics of digital interactions to ensure that technology promotes rather than inhibits social learning (Rustandi et al., 2024). Professional training and institutional resources are frequently used to help people improve these skills (Bandura, 2023; Caena & Redecker, 2019).

Access to technology infrastructure and supportive education policies are crucial for the development of TDC. Schools that provide enough resources and training opportunities allow instructors to improve their digital competence more effectively (Rustandi et al., 2024; Zhou et al., 2023). Teachers' self-efficacy, work happiness, and attitudes towards technology all have a substantial impact on their digital competence. Those with better self-efficacy and positive views toward technology have higher levels of digital competence (Zhou et al., 2023). Teachers in schools with a rich informational environment are more likely to be digitally competent.

RESEARCH METHODOLOGY

The researcher chose to use a mixed method with an explanatory design. This method involves merging (uniting or combining), connecting (connecting or creating a database that explains another database), building (building or creating a new base that can be used in another database) and embedding (embedding or placing one database in another larger database) (Creswell & Creswell, 2018). The problems in this study were raised through a quantitative approach, where later qualitative data will emerge that will explain the quantitative data. The crucial aspect in justifying a mixed methodology research design is that both single methodology approaches (qualitative only and quantitative only) have strengths and weaknesses (Kelle, 2006; van Griensven et al., 2014). The combination of methodologies, on the other hand, can focus on their relevant strengths.

The research analysis unit is all teachers who teach in public senior high schools in Jakarta, which have the status of driving schools . The population is 1069 teachers, while the research sample after being calculated using the Slovin formula at a margin of error of 5% (0.05) obtained 291 respondents. The sampling technique used is random sampling where each member of the population has an equal opportunity to be a sample. The data collection technique is through a google form link that is distributed to teachers. Furthermore, semi-structured interviews were conducted to obtain

qualitative data while exploring the principal's completeness leadership strategy in improving teacher digital competence.

Table 1. Data collection technique

Data Types	Variable Instruments	Data collection technique	Data source
Quantitative	Teacher digital competency questionnaire	Survey	Teacher
	Complexity leadership questionnaire	Survey	Teacher

Variable of teacher digital competence (Y)

Teacher digital competence is a set of knowledge, skills, and attitudes needed by educators to effectively integrate digital technology into teaching practices that include the ability to plan, teach, and evaluate technology-assisted learning. Indicators of teacher digital competence include professional engagement, digital devices, technology integration into learning, learning assessment, and student empowerment.

Variable of principal's complexity leadership (X)

The complexity leadership of the principal is a leadership that is a facilitator to encourage adaptability, creativity, and collaboration in facing complex challenges, where leaders do not only focus on top-down decision making, but also pay attention to the complex interactions between various factors and elements in the system in the school environment. The main characteristics of *the complexity leadership* of the principal include adaptive leadership, administrative leadership, shared leadership, and leader behavior.

The Likert assessment scale is used for all variables that have five answer categories. For the teacher digital competence variable , if the statement is positive: always = 5; often = 4; sometimes = 3; rarely = 2; and never = 1. If the statement is negative: always = 1; often = 2; sometimes = 3; rarely = 4; and never = 5. While *the complexity leadership* variable , if the statement is positive: strongly agree = 5; agree = 4; disagree = 3; disagree = 2; and strongly disagree = 1. If the statement is negative: strongly agree = 1; agree = 2; disagree = 3; disagree = 4; and strongly disagree = 5.

Data processing in this study uses SPSS software version 25. While the data analysis technique of this study is hypothesis testing. A hypothesis can be accepted or rejected statistically based on its level of significance. The significance threshold used in this study is 5%. If the specified level of significance is 5%, then the level of significance or level of confidence to reject the hypothesis is 0.05. This study has a 5% chance of making a bad judgment and a 95% chance of making a good decision. The research hypothesis is described as follows:

$H_0 = \rho_{yx} \leq 0$ (there is no influence of the principal's complexity leadership on teachers' digital competence)

$H_1 = \rho_{yx} \geq 0$ (there is an influence of the principal's complexity leadership on teachers' digital competence)

RESULTS

One of the major challenges for teachers is mastering the ever-evolving digital competencies. Digital skills are crucial in supporting a more effective and innovative learning process, especially with the development of educational technology. Principals, as leaders, need to encourage the development of teachers' digital competencies by providing relevant training, building a digital learning culture in schools, and facilitating the use of technology in teaching and learning activities.

The results of the calculation of the influence of the principal's *complexity leadership* on teachers' digital competence can be seen in Table 2 below.

Table 2. Coefficients Values

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
	(Constant)	35.225	5.250		6,709	.000
	Complexity Leadership of Principals	.363	.057	.482	6,384	.000
a. Dependent Variable: Teacher's Digital Competence						

From the test results of Table 2 above, the constant (a) is = 35.225 and the regression coefficient (b) = 0.363. Thus, the regression equation is obtained as $\hat{Y}$ = 35.225 + 0.363X. Furthermore, the results of the coefficient calculation show the influence of the principal's complexity leadership on the digital competence of teachers, where ρ_{yx} = 0.363, sig. = 0.000 <0.05, while the $_{calculated}$ t value = 6.384, while the $t_{table\ value}$ at the significance level α (0.0 5) and N = 137 is 1.66. Because the $_{calculated}$ $t > t_{table}$, H_0 is rejected and H_1 is accepted. Thus, it can be concluded that the principal's complexity leadership has a positive influence on the digital competence of high school teachers . This reflects that this leadership model involves the principal's ability to manage uncertainty, adapt to change, and manage dynamics in an ever-evolving environment. The higher this leadership model is implemented in schools, the more teachers' digital skills will increase.

Table 3. Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.782 [a]	.532	.526	10,229
a. Predictors: Complexity Leadership of Principals				
b. Dependent Variable: Teacher's Digital Competence				

The determination coefficient value from the summary model table shows Rsquare = 0.532, which means that $R2 = (0.532)^2 = 0.2830$ or 28.30% of teachers' digital competence can be explained by the principal's complexity leadership . The rest, which is 71.70%, is influenced by other factors not explained in the study such as organizational culture, school climate, facilities, intrinsic motivation, and organizational commitment. Thus, it can be concluded that the principal's complexity leadership has a significant influence on improving teachers' digital competence, although there are other factors that play a role.

The urgency of complexity leadership is increasingly recognized in various fields, as this model addresses the dynamic and interconnected nature of modern organizational environments. The complexity leadership model emphasizes the need for an adaptive, systemic, and relational approach to leadership, which is critical in navigating the challenges posed by complex systems. In educational settings, the complexity leadership model helps assess and develop leadership competencies that are critical to effective teaching and learning (Parreira et al., 2018).

Figure 1 explains how complexity leadership The principal consists of four indicators that influence the digital competencies of teachers currently needed.

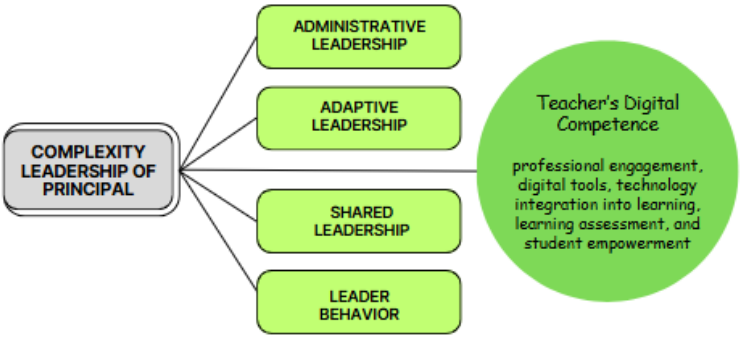

Figure 1. Four Indicators of the Complexity Leadership Model of Principal

Complexity leadership model The principal in improving the digital competence of teachers refers to several aspects including (1) Administrative leadership of principal with indicators of formulating policies and strategies, compiling tasks, being involved in planning, building a vision, empowering resources to achieve goals, conflict management, organizational strategy management and coordination; (2) Adaptive leadership of principal with indicators of cooperation, providing new ideas for organizational goals, collaborative, creativity, building organizational culture, building strong trust and providing space for team members to develop skills; (3) Shared leadership of principal with indicators of coordinated actions, working relationships, solutions to problems and decision making; (4) Leader behavior of principal with indicators of developing system networks, creating shared meaning, reducing tension and building social partnerships.

Administrative leadership of principal

The administrative leadership of the principal is an important aspect in managing and advancing education in schools. An effective principal not only acts as an academic leader, but also as an administrative leader who has the responsibility to manage the organization, formulate policies, and ensure that the school's vision and mission are achieved. Through a clear and structured administrative leadership strategy, the principal can create an environment that supports the development of digital competence. Policies that support digitalization, compile tasks that are oriented towards the use of technology, and are actively involved in planning and management, the principal can direct the school to improve digital competence for both teachers, staff, and students. The principal is able to manage conflict, coordinate various parties, and build a strong vision will facilitate the process of adopting technology and create a school that is better prepared to face the challenges of the times.

Adaptive leadership of principal

Adaptive leadership of the principal is a leadership approach that focuses on the ability to adapt to change, face new challenges, and continue to grow with the team and organization. Principals with adaptive leadership not only manage the school, but also guide staff and students to thrive in the face of ever-changing educational challenges. This leadership requires the ability of leaders to think strategically, be open to change, and always look for ways to involve all parties in the educational process. Each indicator supports each other and strengthens the position of the principal as a leader who not only manages, but also empowers the entire school community to continue to grow.

Shared leadership of principal

Principal-led leadership is a collaborative approach involving the principal and all members of the management team (such as vice principals, teachers, staff, and other stakeholders) to jointly manage and lead the school. The four indicators such as coordinated action, working relationships, problem solving, and decision making are pillars that support each other to create a healthy, productive, and innovative school environment. In shared leadership, each individual has an important role and responsibility to jointly realize the school's vision and mission.

Leader behavior of principal

The principal has a very strategic role in directing and facilitating the development of digital competence for both teachers, students, and the entire school community. Through effective leadership behavior, the principal can create a technology-based learning culture, which not only enriches the learning experience but also prepares students to face the challenges of the 21st century. In this case, the principal's leadership behavior can be described through various indicators, such as supporting shared leadership, developing system networks, creating shared meaning, reducing tension, and building social partnerships. Each of these indicators has a mutually supportive role in improving digital competence in the school environment, both through developing individual capacity and strengthening collaboration between all related parties.

DISCUSSION

The complexity of leadership and digital competence among teachers is a very important topic in the context of modern education. Along with the rapid development of technology, teachers are required to adapt and integrate digital tools into their teaching practices. Effective leadership from the principal is very important in creating an environment that supports teacher competence (Day et al., 2020; Meyer et al., 2022). The principal acts as an educator, manager, and leader who can create a positive work climate and encourage teacher professional development (Liu & Hallinger, 2018). Although leadership has a significant influence on teacher performance, the direct impact of teacher competence on performance is more difficult to observe. However, good leadership, competence, and motivation can simultaneously improve overall teacher performance.

The influence of principal complexity leadership on teachers' digital competence can be explained through three aspects in the theory of complexity leadership, including adaptive leadership, administrative leadership, and enabling leadership (Uhl-Bien et al., 2007). Adaptive leadership plays an important role in developing teachers' ability to adapt to new conditions, such as the development of digital technology. With this approach, principals can encourage teachers to think creatively, solve problems, and develop innovations in the use of digital tools for learning (Baltaci & Balcı, 2017; Marion & Uhl-Bien, 2001). On the other hand, administrative leadership ensures that organizational processes run well and are structured, providing a stable framework to support changes in the education system (Baltaci & Balcı, 2017). However, administrative leadership must be balanced with enabling leadership, which focuses on creating conditions that support interaction and collaboration between teachers to improve their digital abilities. In this context, the principal acts as a facilitator who creates a conducive environment for the development of teachers' digital competence through training, discussion, and knowledge exchange (Uhl-Bien, 2021). By combining these three dimensions of leadership, principals can effectively improve teachers' digital competencies, which in turn contributes to improving the quality of learning in the digital era.

In education, principals have a critical role in guiding online learning initiatives. They must balance administrative direction with enabling leadership, allowing them to manage the diverse needs of teaching and evolving educational demands (Watts, 2019). In the healthcare context, Complexity leadership emphasizes the importance of adaptability and collaboration, replacing traditional bureaucratic approaches. Nursing leaders are encouraged to enhance the adaptability of the system, rather than simply applying top-down directives (Uhl-Bien, 2021). Meanwhile, in engineering and industry, a framework developed for a multinational engineering organization demonstrates the importance of integrating multiple leadership modes to achieve agility and structure in a complex environment (Biggadike et al., 2024).

Complexity leadership shifts focus from traditional hierarchical models to adaptive frameworks that emphasize self-organization and distributed cognition. This approach allows organizations to respond more effectively to complex and volatile environments by fostering collaborative leadership and continuous innovation (Walker et al., 2024). Leaders are encouraged to establish clear yet flexible goals, promote transparency, and embrace diversity to create conditions for bottom-up self-

organization. This involves loosening central control to allow decentralized experimentation and developing networked mindsets through cross-functional teams (Uhl-Bien & Arena, 2018).

In healthcare, complexity theories inform leadership by encouraging a mindset that resists prescriptive recommendations, instead focusing on emergent themes and adaptive strategies (Curlee & Gordon, 2010; Marion & Uhl-Bien, 2001). Coproduction leadership in public services involves relational partnerships and power-sharing, requiring leaders to navigate complex interactions and establish trust and communication networks (Kjellström et al., 2024).

CONCLUSION

The principal's complexity leadership has a positive and significant influence on increasing teachers' digital competence by 28.30%. Other factors such as organizational culture, school climate, facilities, intrinsic motivation, and organizational commitment also influence teachers' digital competence, with a contribution of 71.70%. Therefore, it is important to pay attention to other aspects that also influence teachers' digital competence. The principal's complexity leadership model has four main characters. First, the principal's administrative leadership that focuses on policy formulation, strategy management, and resource empowerment. Second, adaptive leadership that prioritizes cooperation, collaboration, and providing space for teacher skill development. Third, shared leadership that emphasizes the importance of coordination of actions, working relationships, and effective decision making. Fourth, leadership behavior that strengthens the system network, and creates shared meaning to build harmonious social partnerships. These four aspects are interrelated to create an environment that supports the development of teachers' digital competence effectively.

The study has limitations that come from various factors such as theories and research results as well as cultural and institutional differences. Most research on Complexity Leadership has developed in the private sector, where the main focus is on adaptive and responsive organizational management to rapid changes in the business environment. In the context of education, especially in schools, this concept is still very minimally applied or researched. Education, as an institution that is more static than the business world, requires a leadership approach that considers specific factors such as curriculum, student character, and government policies that may not always be as flexible as the industrial world. Suggestion: researchers can use indicators of administrative leadership, adaptive leadership, shared leadership and principal behavior as independent variables in further research.

DECLARATIONS

We declare that there are no conflicts of interest. This article has not been published in any other journal and is not currently under consideration by another journal.

REFERENCES

Baltaci, A., & Balcı, A. (2017). Complexity Leadership: A Theorical Perspective. *International Journal of Educational Leadership and Management*, *5*(1), 30-58. https://doi.org/10.17583/ijelm.2017.2435

Bandura, A. (2023). Cultivate Self-Efficacy for Personal and Organizational Effectiveness. In *Principles of Organizational Behavior* (pp. 113–135). John Wiley & Sons, Ltd. https://doi.org/10.1002/9781394320769.ch6

Basilotta-Gómez-Pablos, V., Matarranz, M., Casado-Aranda, L.-A., & Otto, A. (2022). Teachers' digital competencies in higher education: A systematic literature review. *International Journal of Educational Technology in Higher Education*, *19*(1), 8. https://doi.org/10.1186/s41239-021-00312-8

Biggadike, C., Pei, E., & Evans, R. (2024). *Complexity Leadership in Multinational Engineering Organizations: A 5-Point Framework* (SSRN Scholarly Paper No. 4815573). Social Science Research Network. https://doi.org/10.2139/ssrn.4815573

Caena, F., & Redecker, C. (2019). Aligning teacher competence frameworks to 21st century challenges: The case for the European Digital Competence Framework for Educators (. *European Journal of Education*, *54*(3), 356–369. https://doi.org/10.1111/ejed.12345

Chiu, T. K. F., Falloon, G., Song, Y., Wong, V. W. L., Zhao, L., & Ismailov, M. (2024). A self-determination theory approach to teacher digital competence development. *Computers & Education*, *214*, 105017. https://doi.org/10.1016/j.compedu.2024.105017

Clarke, N. (2013). Model of complexity leadership development. *Human Resource Development International*, *16*(2), 135–150. https://doi.org/10.1080/13678868.2012.756155

Creswell, J. W., & Creswell, J. D. (2018). Research Design: Qualitative, Quantitative, and Mixed Methods Approaches. *SAGE Publications, Inc.*

Curlee, W., & Gordon, R. L. (2010). *Complexity Theory and Project Management*. John Wiley & Sons.

Dawson, S., Poquet, O., Colvin, C., Rogers, T., Pardo, A., & Gasevic, D. (2018). Rethinking learning analytics adoption through complexity leadership theory. *Proceedings of the 8th International Conference on Learning Analytics and Knowledge*, 236–244. https://doi.org/10.1145/3170358.3170375

Day, C., Sammons, P., & Gorgen, K. (2020). *Successful School Leadership*. Education Development Trust. https://eric.ed.gov/?id=ED614324

Diachuk, O. (2024). Development of digital competence of teachers in vocational education institutions. *Scientia et Societus*, *1*(3), 77-91. https://doi.org/10.69587/ss/1.2024.77

Donkor, F., & Zhou, D. (2019). Complexity Leadership Theory: A Perspective for State-Owned Enterprises in Ghana. *International Journal of Educational Leadership and Management*, *7*(2), 139–170.

Falloon, G. (2020). From digital literacy to digital competence: The teacher digital competency (TDC) framework. *Educational Technology Research and Development*, *68*(5), 2449–2472. https://doi.org/10.1007/s11423-020-09767-4

Fernández-Batanero, J. M., Montenegro-Rueda, M., Fernández-Cerero, J., & García-Martínez, I. (2022). Digital competences for teacher professional development. Systematic review. *European Journal of Teacher Education*, *45*(4), 513–531. https://doi.org/10.1080/02619768.2020.1827389

Gibbs, L., Press, F., & Wong, S. (2019). Complexity leadership theory: A framework for leading in Australian early childhood education settings. In P. Strehmel, J. Heikka, E. Hujala, J. Rodd, & M. Waniganayake (Eds.), *Leadership in Early Education in Times of Change* (1st ed., pp. 173–186). Verlag Barbara Budrich. https://doi.org/10.2307/j.ctvmd84fc.16

Guillén-Gámez, F. D., Mayorga-Fernández, M. J., & Álvarez-García, F. J. (2020). A Study on the Actual Use of Digital Competence in the Practicum of Education Degree. *Technology, Knowledge and Learning*, *25*(3), 667–684. https://doi.org/10.1007/s10758-018-9390-z

Haseeb, A., Xia, E., Saud, S., Ahmad, A., & Khurshid, H. (2019). Does information and communication technologies improve environmental quality in the era of globalization? An empirical analysis. *Environmental Science and Pollution Research*, *26*(9), 8594–8608. https://doi.org/10.1007/s11356-019-04296-x

Hazy, J. K., & Uhl-Bien, M. (2015). Towards operationalizing complexity leadership: How generative, administrative and community-building leadership practices enact organizational outcomes. *Leadership*, *11*(1), 79–104. https://doi.org/10.1177/1742715013511483

Howard, S. K., Tondeur, J., Ma, J., & Yang, J. (2021). What to teach? Strategies for developing digital competency in preservice teacher training. *Computers & Education*, *165*, 104149. https://doi.org/10.1016/j.compedu.2021.104149

Hunt, J. G., & Dodge, G. E. (2000). Leadership déjà vu all over again. *The Leadership Quarterly*, *11*(4), 435–458. https://doi.org/10.1016/S1048-9843(00)00058-8

Kelle, U. (2006). Combining qualitative and quantitative methods in research practice: Purposes and advantages. *Qualitative Research in Psychology*, *3*(4), 293–311. https://doi.org/10.1177/1478088706070839

Kjellström, S., Sarre, S., & Masterson, D. (2024). The complexity of leadership in coproduction practices: A guiding framework based on a systematic literature review. *BMC Health Services Research*, *24*(1), 219. https://doi.org/10.1186/s12913-024-10549-4

Lestari, W. D., Pertiwi, S., Rizki, A., Sari, E., & Karnati, N. (2024). Effective Leadership In The Digital Age: Challenges And Strategies In Education. *Jurnal Edusci*, *2*(2), 69-79. https://doi.org/10.62885/edusci.v2i2.501

Lichtenstein, B. B., & Plowman, D. A. (2009). The leadership of emergence: A complex systems leadership theory of emergence at successive organizational levels. *The Leadership Quarterly*, *20*(4), 617–630. https://doi.org/10.1016/j.leaqua.2009.04.006

Lichtenstein, B., Uhl-Bien, M., Marion, R., Seers, A., Orton, J., & Schreiber, C. (2006). Complexity leadership theory: An interactive perspective on leading in complex adaptive systems. *Department of Management: Faculty Publications*. https://digitalcommons.unl.edu/managementfacpub/8

Lindfors, M., Pettersson, F., & Olofsson, A. D. (2021). Conditions for professional digital competence: The teacher educators' view. *Education Inquiry*, *12*(4), 390–409. https://doi.org/10.1080/20004508.2021.1890936

Liu, S., & Hallinger, P. (2018). Principal Instructional Leadership, Teacher Self-Efficacy, and Teacher Professional Learning in China: Testing a Mediated-Effects Model. *Educational Administration Quarterly*, *54*(4), 501–528. https://doi.org/10.1177/0013161X18769048

Marion, R., & Uhl-Bien, M. (2001). Leadership in complex organizations. *The Leadership Quarterly*, *12*(4), 389–418. https://doi.org/10.1016/S1048-9843(01)00092-3

Meyer, A., Richter, D., & Hartung-Beck, V. (2022). The relationship between principal leadership and teacher collaboration: Investigating the mediating effect of teachers' collective efficacy. *Educational Management Administration & Leadership*, *50*(4), 593–612. https://doi.org/10.1177/1741143220945698

Mishra, P., & Koehler, M. J. (2006). Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge. *Teachers College Record*, *108*(6), 1017–1054. https://doi.org/10.1111/j.1467-9620.2006.00684.x

Murray, J. (2017). Complexity Leadership and Collective Action in the Age of Networks. *College English*, *79*(5), 512–525.

Nooteboom, S. G., & Termeer, C. J. A. M. (2013). Strategies of Complexity Leadership in Governance Systems. *International Review of Public Administration*, *18*(1), 25–40. https://doi.org/10.1080/12294659.2013.10805238

Oberländer, M., Beinicke, A., & Bipp, T. (2020). Digital competencies: A review of the literature and applications in the workplace. *Computers & Education*, *146*, 103752. https://doi.org/10.1016/j.compedu.2019.103752

Parreira, A., Pestana, M. H., & Oliveira, P. (2018). Assessing educational leadership: A competence-complexity based test. *Ensaio: Avaliação e Políticas Públicas Em Educação*, *26*, 890–910. https://doi.org/10.1590/S0104-40362018002601559

Rubach, C., & Lazarides, R. (2021). Addressing 21st-century digital skills in schools – Development and validation of an instrument to measure teachers' basic ICT competence beliefs. *Computers in Human Behavior*, *118*, 106636. https://doi.org/10.1016/j.chb.2020.106636

Rustandi, J., Ansori, M. R., Fahlepi, R., Iriansyah, I., & Marliat, M. (2024). Teacher competence in the digital era a phenomenological study. *Jurnal Konseling Pendidikan Islam*, *5*(2), 527-534. https://doi.org/10.32806/jkpi.v5i2.212

Schophuizen, M., Kelly, A., Utama, C., Specht, M., & Kalz, M. (2023). Enabling educational innovation through complexity leadership? Perspectives from four Dutch universities. *Tertiary Education and Management*, *29*(4), 471–490. https://doi.org/10.1007/s11233-022-09105-8

Seufert, S., & Scheffler, N. (2018). Developing Digital Competences of Vocational Teachers. In *Digital Multimedia: Concepts, Methodologies, Tools, and Applications* (pp. 199–216). IGI Global Scientific Publishing. https://doi.org/10.4018/978-1-5225-3822-6.ch010

Skantz-Åberg, E., Lantz-Andersson, A., Lundin, M., & Williams, P. (2022). Teachers' professional digital competence: An overview of conceptualisations in the literature. *Cogent Education*, *9*(1), 2063224. https://doi.org/10.1080/2331186X.2022.2063224

Starkey, L. (2020). A review of research exploring teacher preparation for the digital age. *Cambridge Journal of Education*, *50*(1), 37–56. https://doi.org/10.1080/0305764X.2019.1625867

Tang, Y. M., Lau, Y., & Chau, K. Y. (2022). Towards a sustainable online peer learning model based on student's perspectives. *Education and Information Technologies*, *27*(9), 12449–12468. https://doi.org/10.1007/s10639-022-11136-y

Tsai, Y.-S., Poquet, O., Gašević, D., Dawson, S., & Pardo, A. (2019). Complexity leadership in learning analytics: Drivers, challenges and opportunities. *British Journal of Educational Technology*, *50*(6), 2839–2854. https://doi.org/10.1111/bjet.12846

Uhl-Bien, M. (2021). Complexity Leadership and Followership: Changed Leadership in a Changed World. *Journal of Change Management*, *21*(2), 144–162. https://doi.org/10.1080/14697017.2021.1917490

Uhl-Bien, M., & Arena, M. (2017). Complexity leadership: Enabling people and organizations for adaptability. *Organizational Dynamics*, *46*(1), 9–20. https://doi.org/10.1016/j.orgdyn.2016.12.001

Uhl-Bien, M., & Arena, M. (2018). Leadership for organizational adaptability: A theoretical synthesis and integrative framework. *The Leadership Quarterly*, *29*(1), 89–104. https://doi.org/10.1016/j.leaqua.2017.12.009

Uhl-Bien, M., Marion, R., & McKelvey, B. (2007). Complexity Leadership Theory: Shifting leadership from the industrial age to the knowledge era. *The Leadership Quarterly*, *18*(4), 298–318. https://doi.org/10.1016/j.leaqua.2007.04.002

Uhl-Bien, M., Meyer, D., & Smith, J. (2020). Complexity Leadership in the Nursing Context. *Nursing Administration Quarterly*, *44*(2), 109. https://doi.org/10.1097/NAQ.0000000000000407

van Griensven, H., Moore, A. P., & Hall, V. (2014). Mixed methods research – The best of both worlds? *Manual Therapy*, *19*(5), 367–371. https://doi.org/10.1016/j.math.2014.05.005

Walker, S. M., Watkins, D. V., & Earnhardt, M. P. (2024). Complexity Leadership: The Third Decade. *Journal of Leadership, Accountability and Ethics*, *21*(4), 25-47. https://doi.org/10.33423/jlae.v21i4.7370

Watts, T. (2019). Complexity leadership: The Role of Teaching and Learning Center Leaders in Online Learning at Small, Private Colleges. *Theses and Dissertations--Education Sciences*. https://doi.org/10.13023/etd.2019.307

Zhou, P., Yu, Y., Zhang, Y., Li, Y., & Tang, Y. (2023). Exploring Factors Influencing Teachers' Digital Competence Based on the Social Cognitive Theory. *2023 Twelfth International Conference of Educational Innovation through Technology (EITT)*, 56–60. https://doi.org/10.1109/EITT61659.2023.00018