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Technological Leadership and ICT Literacy as Keys to Increasing Innovative Teacher Behavior

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ABSTRACT

Purpose-Technological leadership and ICT literacy are important factors in improving teachers' innovative behavior. This study is essential, considering the rapid development of information technology that requires teachers to innovate. This study aims to analyze the direct influence of technological leadership and ICT literacy on innovative teacher behavior, the direct influence of technological leadership on ICT literacy, and the indirect influence of technological leadership on innovative behavior through ICT literacy.

Methodology-This study uses path analysis. The sample of this study was 136 private high school teachers in Depok City, West Java, obtained through multistage random sampling techniques.

Findings-Technological leadership positively and significantly influences teachers' innovative behavior with a p-value of 0.000 (<0.05). ICT literacy also positively and significantly influences teachers' innovative behavior, with a p-value of 0.001 (<0.05). Technology leadership has a positive and significant direct effect on ICT literacy, with a p-value of 0.000 (<0.05). The indirect impact of technology leadership on teacher innovative behavior through ICT literacy is insignificant, with a p-value of 0.857 (>0.05). ICT literacy has not played a significant role as a mediator, where the direct effect is stronger than the indirect effect.

Significance- The strategy that can be used to improve teacher innovative behavior is to strengthen technology leadership and ICT literacy. Improving technology leadership can be achieved by improving technology infrastructure and fostering professional excellence for principals. Meanwhile, ICT literacy can be strengthened by providing teachers with skills to create, manage, access, and disseminate information, contribute to public knowledge, and understand the legal aspects of ICT.

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INTRODUCTION

Teachers have a strategic role in supporting the achievement of educational goals. Achieving this requires innovative behavior for each teacher (Pradana & Izzati, 2019). Creative behavior is urgently needed in facing the ongoing challenges in the digital era, where teachers are not only responsible for teaching students about knowledge, skills, and attitudes according to the standard syllabus determined by the Ministry but are also encouraged to be innovative in their teaching (Ismail & Mydin, 2019; Asbari et al., 2019). The teacher's innovative behavior is exploring opportunities, generating ideas, promoting ideas, realizing ideas, and reflecting on their professional work as a result of the accumulation of physical and cognitive work to increase the effectiveness of achieving learning quality. Research on improving teachers' innovative behavior is essential, considering that the rapid development of technology and information requires teachers to continue to innovate so that learning models are relevant and practical, can encourage creativity and critical thinking skills, and prepare students to face global competition (Sofyani et al., 2019; Chen, 2024). On the other hand, based on preliminary research on private high school teachers in Depok City, West Java, information was obtained that 35.56% of teachers were still low in exploring opportunities, 40.00% of teachers were still low in generating ideas, 43.33% of teachers were still low in promoting ideas; 45.56% of teachers were still low in realizing ideas; and 36.67% of teachers were still low in evaluating ideas that had been discovered.

Technology has developed rapidly to support the development of teachers' abilities to teach according to their field of expertise. Teacher behavior in adapting to various technological devices in the modern era is necessary. Innovative teachers will be able to adapt to the times quickly and can contribute to developing learning. One of the technological developments that significantly contributes to this regard is related to the use of e-learning in learning. Teachers must be able to adapt to using e-learning on an ongoing basis. Based on various studies that have been carried out, it has been found that the use of learning media during learning has a very positive impact on students (Buzov, 2014; Dumitrica, 2017; Hafifah & Sulistyo, 2020). Learning becomes more active by involving interaction between students through e-learning media. Comments from students can be responded to by the teacher and by classmates. Learning using this technological approach is very helpful in distance learning. Efforts to improve the quality of teachers must be accompanied by innovative behavior and literacy of information and technology (Handayani et al., 2020; Quieng et al., 2015; Radovanović et al., 2020). In addition to literacy, teacher leadership is also needed in classroom teaching.

Innovative teacher behavior is reflected in observing, listening, and adapting ideas, building action strategies, assessing through reflection and evaluation, and adapting innovations (Messmann & Mulder, 2011). Teachers with innovative behavior are teachers who can work creatively and provide positive results for the organization where they work (Izzati, 2018). Creative behavior is one's initiative to actualize the belief in ideas, from creating the idea until the concept can be realized. These three stages indicate that it has not been said to be an innovative behavior if the idea is still only in the form of generalization and promotion. Innovative behavior must go beyond both by being able to realize the ideas they have.

Innovative behavior is closely related to technology. Therefore, increasing innovative behavior can be achieved by strengthening school principals' technological leadership and teachers' ICT literacy. 21st-century principals must be leaders in technology implementation because, in addition to improving learning, they must also enhance their organizational management (Hamzah et al., 2016; Chang, 2019). Technological leadership is a leadership style that focuses on the leader's character in raising the workforce's morale to apply technology in the organization (Raman et al., 2019; Omar & Ismail, 2020). Principals with vision, planning, management, interpersonal, and communication skills will allow teachers to explore opportunities and generate ideas to integrate technology into the learning process and improve the quality of school services. Principals who support technology infrastructure, teacher development and training, professional practice excellence, digital teaching, and learning culture, as well as develop digital citizenship, will provide opportunities for teachers to promote their latest ideas and put these ideas into practice. Then, the principal

who conducts evaluations and assessments will make teachers reflect on their innovative behavior (Alrawili et al., 2020; Liefländer & Bogner, 2018; Maclean & Pavlova, 2017; Maryani et al., 2021).

As stated earlier, increasing innovative behavior requires strengthening ICT literacy. Information and Communication Technology (ICT) literacy is a person's ability to use digital technology, communication equipment, and internet networks to access, manage, integrate, evaluate, and create information as an information function in society (Saripudin et al., 2018; Nur Hafifah & Harry Sulistyo, 2020). Teachers are at the heart of educational institutions and must play a central role in utilizing technology, particularly ICT tools, in teaching and learning (Amua-Sekyi & Asare, 2016). Teachers who know ICT will explore existing opportunities to generate innovation. Teachers who can access/use ICT in various forms, manage ICT, and integrate ICT will generate ideas, promote ideas, and realize their ideas in innovative work practices. Then, teachers who can evaluate ICT, create information to function in the knowledge society, and understand the various ethical, legal, and socioeconomic issues surrounding ICT will reflect on their activities so that they have good effectiveness in learning activities and school services. Other. Based on the discussion, it is necessary for the principal's technological leadership and the teacher's ICT literacy to improve teachers' innovative behavior.

Teachers' innovative behavior can be encouraged by technological leadership carried out by the principal (Keane et al., 2020). Technological leadership has a direct positive and significant effect on teachers' innovative behavior, as evidenced by a Sig value of $0.000 < 0.05$ (Dasmo & Sunardi, 2021). The principal's technological leadership contributes 18.6% to teacher technology integration (Raman et al., 2019). ICT literacy has a direct positive and significant effect on teachers' innovative behavior, as evidenced by a Sig value of $0.036 < 0.05$ (Dasmo & Sunardi, 2021). Meanwhile, (Chou et al., 2019) in their study stated that there was an insignificant direct effect of the acceptance of technological innovation on innovative teaching behavior using ICT with a value of $r = 0.244$ ($t = 0.190$, $p > 0.05$). For principals, sustainable, needs-based technology leadership needs to be optimized to develop technology leaders who can lead schools meaningfully through ICT integration to improve graduates (Sharma, 2019). So far, no research has been found that specifically discusses the influence of principal technology leadership on teacher innovative behavior with ICT literacy as an intervening variable. This research is necessary because teachers' innovative behavior is closely related to their ICT literacy, and the principal will significantly determine this literacy in carrying out technology leadership.

Based on the description above, this study aims to find the direct influence of principal technological leadership and ICT literacy on teachers' innovative behavior, see the direct influence of principal technological leadership on teachers' ICT literacy, and find the indirect impact of principal leadership on teachers' innovative behavior through ICT literacy. This study is expected to be a solution to finding strategies and ways to improve teachers' innovative behavior through strengthening principal technological leadership and teachers' ICT literacy so that it helps improve the quality of learning and education.

METHODOLOGY

Research Design

This research uses path analysis to analyze the direct and indirect influence between one variable and another. The research variables consist of one independent variable (technology leadership), one intervening variable (ICT literacy), and one dependent variable (teacher innovative behavior). The model design that will be used in this research is as follows.

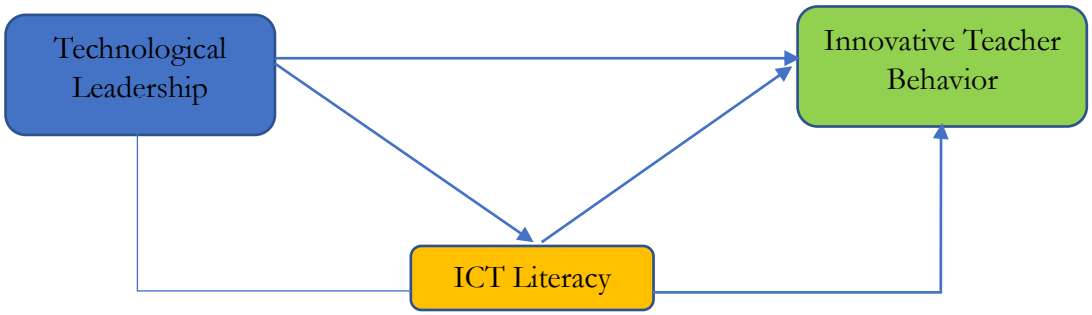

Figure 1. Research Design

Population and Sample

The research was carried out for eight months with a population of 205 private high school teachers in Depok City, West Java. The study was calculated using multistage random sampling, divided into two stages: area sampling and individual sampling. In area sampling, out of 11 sub-districts, eight sub-districts meet the sample fulfillment criteria. Furthermore, in each sub-district, schools are randomly selected to be used as research sites with a proportion of 50% of the number of schools. The sampling results placed 13 schools that would be used as research sites. In the second stage, the researcher conducted individual sampling. Individual sampling was done by calculating the number of teachers in 13 schools. Based on the calculation results, 205 teachers then became the accessible population. By using the Slovin formula, a sample size of 136 teachers was obtained, the determination of which was calculated proportionally by random sampling in each school.

Instrument and Data Collection

Data on technological leadership variables and innovative teacher behavior were collected through an instrument in the form of a rating scale questionnaire with five answer choices (always, often, sometimes, ever, never). Validity testing was carried out using the Pearson Product Moment equation, and reliability testing was carried out using the Cronbach Alpha equation. The innovative behavior and technological leadership instruments used 36 valid statement items each, with a reliability value of 0.96 (high reliability) for innovative behavior and 0.96 (high reliability) for technological leadership. At the same time, ICT literacy used a multiple-choice test instrument. Validity testing was carried out using the Point Biserial equation, and reliability testing was done using the Kuder Richardson-20 equation. This instrument had 38 valid questions with a reliability value of 0.887 (high reliability).

Data Analysis

The research data analysis technique used descriptive analysis, data analysis requirements testing, and hypothesis testing. Research data processing used the SPSS 27.00 application.

Table 1 Research Variable

No	Variable	Indicator	Source
1	Technological Leadership	Vision, planning, and management Personal and communication skills Teacher development and training Technology and infrastructure support Professional practice excellence Digital learning and teaching culture Digital citizenship Evaluation	(Chang, 2019) ; (Banoğlu, 2019)
2	ICT Literacy	Knowledge Access Manage	(Saripudin et al., 2018); (Hafifah & Sulistyo, 2020)

		Integrate Evaluate Create Reflect and judge	
3	Innovative Teacher Behavior	Explore opportunities Generating ideas Promote ideas Realizing the idea Reflecting	(Hansen & Pihl-Thingvad, 2019) ; (Setyaningsih et al., 2019).

Based on the theoretical basis of research design, the hypothesis in this study is:

1. Statistical hypothesis of the direct effect of technological leadership (X1) on teacher innovative behavior (Y).
   H_0: $\beta_{x1y} \leq 0$, There is no direct effect of technological leadership (X1) on teacher innovative behavior (Y).
   H_1: $\beta_{x1y} > 0$. Technological leadership (X1) has a direct effect on teacher innovative behavior (Y).
2. Statistical hypothesis of the direct effect of ICT literacy (X2) on teacher innovative behavior (Y)
   H_0: $\beta_{x2y} \leq 0$, There is no direct effect of ICT literacy (X2) on teacher innovative behavior (Y).
   H_1: $\beta_{x2y} > 0$. ICT literacy (X2) has a direct effect on teacher innovative behavior (Y).
3. Statistical hypothesis of the direct effect of technological leadership (X1) on ICT literacy (X2)
   H_0: $\beta_{x12} \leq 0$, There is no direct effect of technological leadership (X1) on ICT literacy (X2).
   H_1: $\beta_{x12} > 0$, There is a direct effect of technological leadership (X1) on ICT literacy (X2).
4. Statistical hypothesis of the indirect effect of technological leadership (X1) on teacher innovative behavior (Y) through ICT literacy (X2).
   H_0: $\beta_{x12y} \leq 0$, There is no indirect effect of technological leadership (X1) on teacher innovative behavior (Y) through ICT literacy (X2).
   H_1: $\beta_{x12y} > 0$. Technological leadership (X1) has an indirect effect on teachers' innovative behavior (Y) through ICT literacy (X2).

FINDINGS

The findings of this study are presented in the form of data descriptions, analysis requirements testing, and research hypothesis testing. The data description presents the distribution of data (table 2) and the average indicator score analysis (table 3) for each variable. Furthermore, the data analysis requirements are the normality tests (table 4) and the linearity test (table 5). Meanwhile, the hypothesis testing is presented in Table 6. The data were obtained from the data collection results on 136 private high school teachers in Depok City, West Java. Table 2 shows that the innovative behavior of the teacher (Y) is in the sufficient category.

Table 2. Results of Descriptive Data Analysis

No	Statistics	Y	X_1	X_2
1	Mean	140,12	145,46	23,49
2	Median	140,00	145,00	24,00
3	Mode	146,00	145,00	23,00
4	Std. Deviation	10,24	9,69	4,13
5	Variance	104,82	93,924	17,04
6	Minimum	116,00	126,00	13,00
7	Maximum	159,00	169,00	32,00
8	Range	43,00	43,00	19,00

The average value of 140.125 shows that the average respondent's answer is 3.89 (scale 1-5). This condition shows that teachers' innovative behavior is in a reasonably good category but has not shown an optimal number (<4). The principal's technology leadership condition (X1) has an average value of 145.46,

which shows that the average respondent's answer is 4.04 (scale 1-5). This condition indicates that the average respondent's answer to the technology leadership implemented by the principal is in a good category (> 4). Meanwhile, ICT literacy (X2) has an average value (mean) of 23.49, which shows that the average respondent's answer is equivalent to a 71 on a scale of 100 with 33 multiple-choice test questions. This condition indicates that the average teacher has fairly good ICT knowledge but has not shown an optimal number (<80).

Table 3. Average Score of Indicators for Each Variable

No	Variable	Indicator	Average Score
1	Technological Leadership	Vision, planning, and management	4.30
		Personal and communication skills	4.25
		Teacher development and training	3.66
		Technology and infrastructure support	3.81
		Professional practice excellence	3.67
		Digital learning and teaching culture	4.11
		Digital citizenship	4.15
		Evaluation	4.37
2	ICT Literacy	Knowledge	4.02
		Access	3.32
		Manage	3.68
		Integrate	4.02
		Evaluate	3.64
		Create	1.93
		Reflect and judge	3.20
3	Innovative Teacher Behavior	Explore opportunities	4.08
		Generating ideas	3.50
		Promote ideas	3.55
		Realizing the idea	4.13
		Reflecting	3.62

Table 3 shows that there are indicators in each variable whose value is less than 4, which means that the indicator is a priority to be improved immediately (Kane et al., 2016). In the innovative behavior variable, indicators that are still weak and a priority to be improved immediately are generating ideas, promoting ideas, and reflecting. In the technological leadership variable, indicators that are still weak include teacher development and training, technology and infrastructure support, and professional practice excellence. The principal has difficulty providing technology and infrastructure support because the budget control lies with the Foundation. The proposals submitted are often not entirely approved, given their limited budget, likewise, in developing professional practice and teacher development and training. This activity ends in funding issues. In the ICT literacy variable, weak indicators that must be improved immediately are create, manage, access, evaluate, reflect, and judge. Only a few teachers can create, manage, access, and assess ICT in learning. Most teachers are still comfortable with conventional learning systems. On that basis, indicators still weak in teachers' innovative behavior are the ability to generate ideas, promote, and reflect.

Furthermore, the data analysis requirements results show that the data is usually distributed and has a linear pattern. Thus, hypothesis testing is carried out using parametric statistics. The following table summarizes the data analysis requirements.

Table 4 Summary of Normality Tests of Estimated Standard Errors

No	Estimated Standard Error	n	Sig	α	Decision
1	Y over X_1	136	0,338	0,05	Normal
2	Y over X_2	136	0,200	0,05	Normal
3	X_2 over X_1	136	0,200	0,05	Normal

The data normality test was conducted using the Kolmogorov-Smirnov test in SPSS. Data is considered normal if the Sig value > 0.05. Based on Table 4, the results of the standard error normality test of the

estimated innovative behavior of teachers on technological leadership obtained a Sig value of 0.338 > 0.05; innovative behavior of teachers on ICT literacy obtained a Sig value of 0.200 > 0.05; and ICT literacy on technological leadership obtained a Sig value of 0.200 > 0.05. Based on these results, it can be concluded that all data are typically distributed. Meanwhile, table 5 presents the results of the linearity test using the test for linearity in SPSS. Data is considered linear if the Sig value > 0.05. The test results show that the linearity test of innovative behavior of teachers on technological leadership obtained a Sig value of 0.514 > 0.05; innovative behavior of teachers on ICT literacy obtained a Sig value of 0.119 > 0.05; and ICT literacy on technological leadership obtained a Sig value of 0.459 > 0.05. Based on these results, it can be concluded that all data meets the linearity test.

Table 5 Summary of Regression Model Linearity Test

No	Relationship Model between variables	$F_{observe}$	F_{table}	Sig	α	Linearity Test Results
1	Y over X_1	0,979	1,53	0,514	0,05	Linear
2	Y over X_2	1,456	1,69	0,119	0,05	Linear
3	X_2 over X_1	1,017	1,54	0,459	0,05	Linear

Testing the research hypothesis obtained the following results.

Table 6 Hypothesis Testing Results

No	Influence	Coefficient Beta	Sig	observe	table	α	Conclusion
1	X1 --> Y	0,378	0,000	4,876	1,98	0,05	Significance
2	X2 --> Y	0,266	0,001	3,426	1,98	0,05	Significance
3	X1 --> X2	0,313	0,000	3,813	1,98	0,05	Significance
4	X1 --> X2 --> Y	0,083	0,857	0,179	1,978	0,05	Not significant

The results in Table 6 show a significant positive direct effect of technological leadership on teachers' innovative behavior. This is evidenced by the Sig value of 0.000 < 0.05 and observe> table (4.876 > 1.98) at a significance level of 0.05. The beta coefficient of 0.378 indicates that technological leadership has a moderate effect on teachers' innovative behavior. ICT literacy has a significant positive direct effect on teachers' innovative behavior. This is evidenced by the Sig value of 0.001 < 0.05 and observe> table (3.426 > 1.98) at a significance level of 0.05. The beta coefficient of 0.266 indicates that ICT literacy has a slight but perceptible effect on the relationship. Technological leadership has a significant positive direct effect on teachers' ICT literacy. This is evidenced by the Sig value of 0.000 < 0.05 and observe> table (3.813 > 1.98) at a significance level of 0.05. The beta coefficient of 0.313 indicates that technological leadership moderately influences teachers' ICT literacy. There is a positive indirect effect but not significant of technological leadership on teachers' innovative behavior through ICT literacy. This is evidenced by the Sig value of 0.857 > 0.05 and observed < table (0.179 < 1.978). The beta coefficient of 0.083 indicates a weak influence. This condition also shows that ICT literacy as an intervening variable in this study is not strong enough to support the effect of technological leadership on teachers' innovative behavior. ICT literacy has not played a significant role as a mediator, where the direct impact is stronger than the indirect effect.

DISCUSSION

Direct Influence of Technology Leadership on Teachers' Innovative Behavior

Technology leadership has a significant positive direct effect on teachers' innovative behavior. Principals, as individuals who can lead and influence teachers to carry out tasks based on the goals to be achieved, must have technology leadership so that teachers have good innovative behavior. Principals with vision, planning, management, interpersonal, and communication skills will allow teachers to explore opportunities and generate ideas to integrate technology into the learning process and improve the quality of school services. Principals are essential in creating a technology-based learning environment when leading organizations toward digital education (Omar & Ismail, 2020). Successful principals invest and plan

to adopt new technologies, are open to innovations, adopt a school culture that encourages collaborative learning partnerships with teachers, and promote a learning community beyond the classroom. The second challenge for principals lies in delivering appropriate professional development to teachers so that they can integrate technology into their teaching (Keane et al., 2020). Principals in the 21st century must be leaders in technology implementation. Challenges arise because many principals are not sufficiently prepared to lead the implementation and integration of educational technology in schools (Chang, 2019). Technology must be used not only for learning but also in the management of their organization (Hamzah et al., 2016). The success of technological leadership can be seen in Steve Jobs at Apple, who, with his technological leadership, was able to foster innovative employee behavior to create a culture of high-quality production and continuous innovation (Wang, 2024). Based on the description above, this study concludes that principals play an essential role in ensuring that technology is embedded in their organizations to produce innovative teacher behavior. If teachers' innovative behavior is to be improved, it is necessary to strengthen the principal's technological leadership.

Direct Influence of ICT Literacy on Teachers' Innovative Behavior

ICT literacy has a significant positive direct effect on teachers' innovative behavior. Teachers' ability to use sophisticated equipment to produce various messages appropriately will influence teachers' innovative behavior. The strength in developing pedagogy supported by innovative technology lies in teachers' interpretation of the value of the new technology they have learned to support learning. This shows that teachers' innovative behavior will be influenced by their ability to know, understand, and apply existing ICT (ICT literacy). This study corrects the results of (Chou et al., 2019), which stated that there was an insignificant direct influence of the acceptance of technological innovation on innovative teaching behavior using ICT with a value of $r = 0.244$ ($t = 0.190$, $p > 0.05$). Teachers' attitudes towards technology (ICT literacy) need to be significantly and positively improved in their adoption and integration of computers into their teaching. Teachers need appropriate resources and facilities to foster innovative behavior, namely ICT. Teachers need to know what is happening in the school and how everyone involved thinks about the ICT implementation process so that it positively influences their implementation (Messmann & Mulder, 2011). Teachers' educational and ICT beliefs are critical conditions for innovative behavior, especially regarding ICT integration behavior in the classroom. Practical knowledge and professional skills also positively influence the independent use of ICT in the school. In this regard, ICT literacy, in this case, developing specific competencies such as computer use and understanding how computers work, is essential to improve teachers' innovative behavior (Thurlings et al., 2015). Based on the description above, this study concludes that ICT literacy is crucial in enhancing teachers' innovative behavior. Strengthening ICT literacy is needed if teachers' innovative behavior is to be improved.

Direct Effect of Technology Leadership on ICT Literacy

Technology leadership has a significant positive direct effect on teachers' ICT literacy. Technology leadership is essential to enhance the integration of the latest technology while providing all ICT infrastructure for the school community. Principals are also responsible for providing training opportunities and professional development programs for teachers to improve their ICT competency in the latest applications. Therefore, the principal's technological leadership will affect their teachers' ICT literacy. Principals are expected to play a more significant role in integrating ICT in schools, especially in providing incentives, moral support, and teacher training opportunities. Principals are expected to act as role models regarding ICT skills and competencies, promote a culture of innovation, and provide efficient ICT in their schools (Adams & Muthiah, 2020). Leaders who practice technological leadership must have high ICT, develop ICT potential intelligently in the organization, and influence subordinates to use ICT effectively (Omar & Ismail, 2020). This study is in line with the results of (Leong Mei Wei et al., 2016), which showed a statistically significant and quite strong positive correlation ($r = 0.590$, $p < 0.01$) between the principal's technological leadership practices and teacher ICT competencies. Based on the description above, this study

concludes that technological leadership is essential in improving teacher ICT literacy. Strengthening technological leadership is needed if teacher ICT literacy is to be improved.

Indirect Effect of Technological Leadership on Teachers' Innovative Behavior Through ICT Literacy

Technological leadership has a positive indirect effect but is not significant on teachers' innovative behavior through ICT literacy. In this context, the principal's personal and communication skills in implementing technology integration as a characteristic of technological leadership significantly influence innovative behavior without having to foster ICT literacy because the principal's technological leadership is closely related to ICT management that teachers must master. Personal and communication skills will provide direct role models for teachers so that teachers are willing to utilize ICT, improve ICT knowledge and skills to the maximum, and build a collaborative culture in technology integration. ICT literacy is essential for teachers in the 21st century to improve the quality of learning (Anyim, 2019) (Hafifah & Sulistyo, 2020) (Kamsin et al., 2022) Srivastava & Pradhan, 2019). Likewise, digital citizenship and the digital learning culture that is created have automatically produced innovative teacher behavior without having to strengthen teachers' ICT literacy (Maulana et al., 2022). Principals who routinely remind students of the advantages of ICT, become role models in the use of ICT, provide ample opportunities for teachers to use ICT, and provide equal access to the use of ICT devices will result in good innovative behavior (Hatlevik et al., 2018); Kasparova, 2019; (Scherer & Siddiq, 2019). Likewise, in the digital teaching and learning culture indicator, principals who develop electronic learning (e-learning) in learning, create an ICT-based learning environment, and use ICT-based media and devices will encourage teachers to have good innovative behavior. Another indicator is the existence of periodic evaluations by the principal of teachers' innovative activities, which motivate teachers to improve their innovative behavior. (Chou et al., 2019) their research stated that a suitable mediator variable to determine teachers' innovative behavior in using ICT is the innovation climate in the organization(Winangsih & Harahap, 2023). If an organization's climate encourages innovation, it will positively influence teachers to introduce ICT into their classrooms. An environment that fosters innovation in an organization must be cutting-edge, demonstrate a forward-thinking atmosphere, and offer teachers the psychological safety to sustain innovative teaching practices and encourage experimentation.

CONCLUSION

As measured by eight indicators, the principal's technological leadership has a positive and significant influence on teachers' innovative behavior. This means that the better the principal's technological leadership, the better the innovative teacher behavior will be. As measured by seven indicators, ICT literacy has a positive and significant influence on teachers' innovative behavior. This means the better the ICT literacy, the better the innovative teacher behavior. As measured by eight indicators, the principal's technological leadership has a positive and significant influence on teacher ICT literacy. This means that the better the principal's technological leadership, the better the teacher's ICT literacy. ICT literacy is ineffective as a mediating variable for the indirect influence of technological leadership on teachers' innovative behavior.

Innovative behavior is necessary to create an organization that wants to survive at a competitive level and be sustainable. Especially in this disruptive era, innovative behavior is the key to an organization's success in achieving its goals. The rapid development of digital technology is forcing dynamic changes in every aspect of life, including in education. If the school organization, which includes principals and teachers, cannot innovate well, then it is certain that the quality of education will not run optimally. On that basis, innovative behavior needs to be formed and used as a climate and culture in school organizations so that schools have an advantage in facing competition.

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REFERENCES

Adams, D., & Muthiah, V. (2020). School Principals and 21St Century Leadership Challenges: a Systematic Review. *Journal of Nusantara Studies (JONUS)*, *5*(1), 189–210. https://doi.org/10.24200/jonus.vol5iss1pp189-210

Alrawili, K. S., Osman, K., & Almuntasheri, S. (2020). Effect of scaffolding strategies on higher-order thinking skills in science classroom. *Journal of Baltic Science Education*, *19*(5), 718–729. https://doi.org/10.33225/jbse/20.19.718

Amua-Sekyi, E. T., & Asare, P. Y. (2016). A survey of Information Communication Technology literacy among lecturers. *Information and Knowledge Management*, *6*(8), 1–7.

Anyim, W. O. (2019). Assessment of ICT literacy skills of digital library users and staff in Salem University Lokoja, Kogi. *Library Philosophy and Practice*, *2019*(May).

Asbari, M., Santoso, P. B., & Purwanto, A. (2019). Pengaruh Kepemimpinan Dan Budaya Organisasi Terhadap Prilaku Kerja Inovatif Pada Industri 4.0. *JIMUPB: Jurnal Ilmiah Manajemen*, *8*, *No.1*(1), 7–15. https://doi.org/ttps://doi.org/10.33884/jimupb.v8i1.1562

Banoğlu, K. (2019). *Multivariate analysis of school principals' technology leadership competencies, learning school environment and schools' social network structures*. 210.

Buzov, I. (2014). Social Network Sites as Area for Students' Pro-environmental Activities. *Procedia - Social and Behavioral Sciences*, *152*, 1233–1236. https://doi.org/10.1016/j.sbspro.2014.09.304

Chang, I. (2019). *The Relationships among Principals ' Technology Leadership , Teachers ' Learning Community and Innovation Management of Junior High Schools*. *September 2009*, 453–465.

Chen, Y. (2024). Teacher Autonomy, Creative Self-efficacy, and Innovative Behavior: Perspectives from Chinese University EFL Teachers. *Arab World English Journal*, *15*(2), 73–86. https://doi.org/10.24093/awej/vol15no2.5

Chou, C. M., Shen, C. H., Hsiao, H. C., & Shen, T. C. (2019). Factors influencing teachers' innovative teaching behaviour with information and communication technology (ICT): the mediator role of organisational innovation climate. *Educational Psychology*, *39*(1), 65–85. https://doi.org/10.1080/01443410.2018.1520201

Dasmo, D. N., & Sunardi, O. (2021). Increasing Innovative Behavior Through Strengthening Principal's Technology Leadership, Information And Communication Technology Literacy (ICT), And Self …. *Multicultural Education*, *7*(11), 250–256. https://doi.org/10.5281/zenodo.5678903

Dumitrica, D. (2017). Fixing higher education through technology: Canadian media coverage of massive open online courses. *Learning, Media and Technology*, *42*(4), 454–467. https://doi.org/10.1080/17439884.2017.1278021

Hafifah, G. N., & Sulistyo, G. H. (2020). Teachers' ICT literacy and ICT integration in ELT in the Indonesian higher education setting. *Turkish Online Journal of Distance Education*, *21*(3), 186–198. https://doi.org/10.17718/TOJDE.762050

Hamzah, M. I. M., Juraime, F., & Mansor, A. N. (2016). Malaysian Principals' Technology Leadership Practices and Curriculum Management. *Creative Education*, *07*(07), 922–930. https://doi.org/10.4236/ce.2016.77096

Handayani, S., Umi Mintarti, S., Megasari, R., & Omar, N. (2020). Developing of STEM-based learning models for economic education student for facing Industry revolution 4.0 in East Java. *E3S Web of Conferences*, *153*. https://doi.org/10.1051/e3sconf/202015303003

Hansen, J. A., & Pihl-Thingvad, S. (2019). Managing employee innovative behaviour through transformational and transactional leadership styles. *Public Management Review*, *21*(6), 918–944. https://doi.org/10.1080/14719037.2018.1544272

Hatlevik, O. E., Throndsen, I., Loi, M., & Gudmundsdottir, G. B. (2018). Students' ICT self-efficacy and computer and information literacy: Determinants and relationships. *Computers and Education*, *118*(December 2017), 107–119. https://doi.org/10.1016/j.compedu.2017.11.011

Ismail, A., & Mydin, A. A. (2019). *The Impact of Transformational Leadership and Commitment on Teachers' Innovative Behaviour*. *304*(Acpch 2018), 426–430. https://doi.org/10.2991/acpch-18.2019.100

Izzati, U. (2018). *The Relationships between Vocational High School Teachers' Organizational Climate and Innovative Behavior*. *173*(Icei 2017), 343–345. https://doi.org/10.2991/icei-17.2018.91

Kamsin, I. F., Salleh, N. S. M., Zainal, N. K., & Hassan, N. H. (2022). Learning Styles Integration in ICT Literacy Module (mLICT-OA) Development for Orang Asli Students. *International Journal of Information and Education Technology*, *12*(11), 1254–1259. https://doi.org/10.18178/ijiet.2022.12.11.1747

Kane, S. N., Mishra, A., & Dutta, A. K. (2016). Preface: International Conference on Recent Trends in Physics (ICRTP 2016). *Journal of Physics: Conference Series*, *755*(1). https://doi.org/10.1088/1742-6596/755/1/011001

Keane, T., Boden, M., Chalmers, C., & Williams, M. (2020). Effective principal leadership influencing technology innovation in the classroom. *Education and Information Technologies*, *25*(6), 5321–5338. https://doi.org/10.1007/s10639-020-10217-0

Leong Mei Wei, Chua Yan Piaw, & Sathiamoorthy Kannan. (2016). Relationship between principal technology leadership practices and Teacher ICT competency. *Malaysian Online Journal of Educational Management*, *4*(3), 13–36.

Liefländer, A. K., & Bogner, F. X. (2018). Educational impact on the relationship of environmental knowledge and attitudes. *Environmental Education Research*, *24*(4), 611–624. https://doi.org/10.1080/13504622.2016.1188265

Maclean, R., & Pavlova, M. (2017). What type of pedagogy is required in schools and classrooms to support sustainable green growth? A case study of Hong Kong within the international context. In *Education in the Asia-Pacific Region* (Vol. 38, pp. 101–119). Springer Nature. https://doi.org/10.1007/978-981-10-3654-5_7

Maryani, I., Prasetyo, Z. K., Wilujeng, I., Purwanti, S., & Fitrianawati, M. (2021). HOTs Multiple Choice and Essay Questions: A Validated Instrument to Measure Higher-order Thinking Skills of Prospective Teachers. *Journal of Turkish Science Education*, *18*(4), 674–690. https://doi.org/10.36681/tused.2021.97

Maulana, I., Harahap, R. D., & Safitri, I. (2022). Use of learning media through technology for biology education students. *BIO-INOVED : Jurnal Biologi-Inovasi Pendidikan*, *4*(3), 282. https://doi.org/10.20527/bino.v4i3.13418

Messmann, G., & Mulder, R. H. (2011). Innovative Work Behaviour in Vocational Colleges: Understanding How and Why Innovations Are Developed. *Vocations and Learning*, *4*(1), 63–84. https://doi.org/10.1007/s12186-010-9049-y

Omar, M. N., & Ismail, S. N. (2020). Mobile Technology Integration in the 2020s: The impact of technology leadership in the Malaysian context. *Universal Journal of Educational Research*, *8*(5), 1874–1884. https://doi.org/10.13189/ujer.2020.080524

Pradana, G. O., & Izzati, U. A. (2019). Hubungan antara iklim organisasi denganp perilaku inovatif pada guru SMK. *Jurnal Penelitian Psikologi*, *6*(4), 1–6.

Quieng, M. C., Lim, P. P., & Lucas, M. R. D. (2015). 21st century-based soft skills: spotlight on non-cognitive skills in a cognitive-laden dentistry program. *European Journal of Contemporary Education*, *11*(1), 72–81. https://doi.org/10.13187/ejced.2015.11.72

Radovanović, D., Holst, C., Banerjee Belur, S., Srivastava, R., Vivien Houngbonon, G., Le Quentrec, E., Miliza, J., Winkler, A. S., & Noll, J. (2020). Digital literacy key performance indicators for sustainable development. *Social Inclusion*, *8*(2), 151–167. https://doi.org/10.17645/si.v8i2.2587

Raman, A., Thannimalai, R., & Ismail, S. N. (2019). Principals' Technology Leadership and its effect on teachers' technology integration in 21st century classrooms. *International Journal of Instruction*, *12*(4), 423–442. https://doi.org/10.29333/iji.2019.12428a

Saripudin, S., Sumarto, S., Juanda, E. A., Abdullah, A. G., & Ana, A. (2018). Understanding technology literacy: The characteristics of ICT literacy vocational teachers. *International Journal of Engineering and Technology(UAE)*, *7*(4), 182–185. https://doi.org/10.14419/ijet.v7i4.33.23555

Scherer, R., & Siddiq, F. (2019). The relation between students' socioeconomic status and ICT literacy: Findings from a meta-analysis. *Computers and Education*, *138*(0317), 13–32. https://doi.org/10.1016/j.compedu.2019.04.011

Setyaningsih, S., Sukanti, D., & Hardhienata, S. (2019). *Teacher's Innovation Improvement through the Development of Organizational Climate and Emotional Intelligence Using Correlation Statistical Analysis and Sitorem Method*. *253*(Aes 2018), 45–49. https://doi.org/10.2991/aes-18.2019.11

Sharma, S. (2019). Technology Leadership: Principals' Concerns in Leading Schools. *Mier-Journal of Educational Studies Trends and Practices*, *9*(2), 263–276.

Sofyani, N., Susanto, R., Kunci, K., & Belajar, M. (2019). Analisis Keterkaitan Kecerdasan Emosional (Emotional Quotient) Dan Ketahanmalangan (Adversity Quotient) Dalam Pembentukan Motivasi Belajar Siswa Kelas Va Di Sekolah Dasar Negeri Jelambar Baru 01. *Dinamika Sekolah Dasar*, 1–13.

Thurlings, M., Evers, A. T., & Vermeulen, M. (2015). Toward a Model of Explaining Teachers' Innovative Behavior: A Literature Review. *Review of Educational Research*, *85*(3), 430–471. https://doi.org/10.3102/0034654314557949

Wang, R. (2024). Successful Technology Enterprise Founders and Their Leadership. *Highlights in Business, Economics and Management*, *30*, 46–51. https://doi.org/10.54097/143s1a92

Winangsih, E., & Harahap, R. D. (2023). Analisis Penggunaan Media Pembelajaran pada Muatan IPA di Sekolah Dasar. *Jurnal Basicedu*, *7*(1), 452–461. https://doi.org/10.31004/basicedu.v7i1.4433