

Unveiling the Link between Principal Leadership and School Climate in Promoting Deep Learning: The Mediating Role of Teacher Collaboration

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ABSTRACT

It has been relatively scarce regarding empirical evidence on how principal leadership and school climate jointly promote deep learning through the mediating role of teacher collaboration, particularly in school contexts where collaborative professional practices are still developing. This study aims to examine the effect of principal leadership on school climate through teacher collaborative culture as a mediating variable in public senior high schools in East Java, Indonesia. This study employed an explanatory quantitative approach using a survey method. Data were collected from 1,726 respondents, and after a rigorous data screening process, 1,206 valid responses were retained for analysis. The data for this study were collected using a structured questionnaire designed to measure four key constructs: principal leadership, teacher collaborative culture, school climate, and deep learning. The data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM). The findings reveal that principal leadership has a significant effect on teacher collaborative culture ($\beta = 0.685$, $t = 39.368$, $p < 0.001$) and school climate ($\beta = 0.457$, $t = 16.470$, $p < 0.001$). Teacher collaborative culture also significantly influences school climate ($\beta = 0.481$, $t = 17.548$, $p < 0.001$) and acts as a partial mediator ($\beta = 0.330$, $t = 16.588$, $p < 0.001$). This study extends educational leadership theory by showing that principal leadership promotes deep learning through school climate and teacher collaboration. It highlights teacher collaboration as a key mediating mechanism linking leadership practices to meaningful learning. Practically, the findings suggest that school leaders should foster supportive climates, shared instructional goals, and collaborative teacher cultures to strengthen deep learning practices and improve students' critical, reflective, and constructive engagement.

Keywords: Principal Leadership; Leadership Transformation; Teacher Collaboration; School Climate; Deep Learning.



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1. INTRODUCTION

Principal leadership plays a strategic role in enhancing the quality of instruction and student learning outcomes through the strengthening of effective pedagogical practices. A growing body of research indicates that educational leadership exerts a significant influence on academic achievement, both directly and indirectly, by shaping teachers' instructional practices and the

organizational conditions of schools (Day et al., 2016; Meng et al., 2026; Sakız et al., 2026; Yalçın et al., 2025). In the context of 21st-century education, learning is no longer merely oriented toward knowledge transmission but also toward the development of critical, collaborative, and reflective thinking skills, commonly conceptualized as deep learning (Chaudhary & Singh, 2025; Desai et al., 2024).

Leadership that supports the success of deep learning initiatives positions the principal as a change agent who drives the transformation of instructional practices through strengthening teachers' capacities and fostering a conducive learning environment. This perspective underscores the importance of leadership that extends beyond administrative functions to encompass teacher professional development and the cultivation of a supportive school organizational culture (Feldman, 2020; Leithwood et al., 2020; Sun et al., 2024). Within this framework, principals play a pivotal role in articulating a shared vision, supporting instructional innovation, and facilitating teacher collaboration as integral components of the continuous improvement of teaching and learning quality.

Previous research indicates that the influence of principal leadership on instructional quality and student learning outcomes is often indirect, mediated by organizational factors such as teacher collaboration and the school climate (Leithwood et al., 2020; Liu & Hallinger, 2026; Wang et al., 2026). Teacher collaboration enables the exchange of professional knowledge, collective reflection, and the development of more effective instructional practices (Hargreaves & O'Connor, 2025; Rechsteiner et al., 2026; Yan & Peng, 2026). Meanwhile, a positive school climate has been shown to contribute significantly to enhanced student engagement, well-being, and academic achievement (Hu et al., 2025; Thapa & Cohen, 2023).

Although the relationships among principal leadership, teacher collaboration, and school climate have been widely examined (Day et al., 2016; Meng et al., 2026; Sakız et al., 2026; Yalçın et al., 2025). There remains a paucity of studies that simultaneously test the mediating mechanism of teacher collaboration within the context of deep learning. Previous studies have generally investigated these constructs in a fragmented manner, focusing either on the influence of principal leadership on teacher performance (Liu & Hallinger, 2026; Wang et al., 2026). The role of school climate in improving organizational effectiveness, or the contribution of teacher collaboration to instructional quality (Leithwood et al., 2020; Sun et al., 2024). As a result, limited attention has been given to how these variables operate as an integrated process through which leadership and school climate are translated into concrete deep learning practices. Moreover, much of the existing literature has emphasized direct associations among variables, thereby overlooking the possibility that teacher collaboration may function as a critical professional pathway linking school-level conditions to students' deeper engagement, higher-order thinking, and meaningful knowledge construction. Another limitation is that prior research has often been conducted in developed-country contexts, where school governance, teacher autonomy, leadership structures, and professional collaboration cultures may differ substantially from those in developing educational systems. Consequently, the transferability of these findings to contexts with different institutional resources, policy pressures, and collaborative traditions remains uncertain. Addressing these gaps, the present study offers a more comprehensive model by examining teacher collaboration as a mediating mechanism between principal leadership, school climate, and deep learning (Feldman, 2020; Liu & Hallinger, 2026; Özdemir et al., 2023). Therefore, there is a need for research that integrates these three constructs within a comprehensive and contextually grounded model.

School climate and teacher collaboration support the concrete implementation of deep learning by creating organizational and professional conditions that enable teachers to design more meaningful, inquiry-oriented, and student-centered learning experiences (Hargreaves & O'Connor, 2025; Yan & Peng, 2026). A positive school climate provides psychological safety, shared norms, academic trust, and institutional support, allowing teachers and students to engage in reflective dialogue, critical questioning, problem solving, and knowledge construction (Feldman, 2020; Liu & Hallinger, 2026; Özdemir et al., 2023). Within such an environment, teacher collaboration functions as a practical mechanism through which deep learning is translated into classroom practice (Yang & Peng, 2026). Through collaborative lesson planning, peer observation, joint reflection, and the exchange of pedagogical strategies, teachers are better able to design authentic tasks, integrate interdisciplinary learning, and assess students' higher-order thinking. Therefore, school climate provides the enabling context, while teacher collaboration serves as the professional process that transforms the principles of deep learning into sustained instructional practices.

This study offers a novel contribution by empirically examining the mediating role of teacher collaborative culture in the relationship between principal leadership and school climate. Unlike prior studies that predominantly focus on direct effects, this research demonstrates that the influence of leadership on school climate operates through organizational mechanisms, with professional teacher collaboration functioning as a partial mediator. Furthermore, the study enriches the existing literature by providing empirical evidence from the context of Indonesian secondary schools, which remains relatively underexplored in structural model-based educational leadership research. Accordingly, this study aims to analyze the role of principal leadership in shaping school climate through teacher collaborative culture within the context of deep learning in Indonesian secondary education.

2. Literature Review

2.1 Principal Leadership within the Framework of Deep Learning Program

Principal leadership constitutes a central construct in educational effectiveness research, serving as a key determinant of instructional quality and overall school performance. Within contemporary educational leadership theory, principals are conceptualized not merely as administrative managers but as instructional leaders who actively shape teaching practices and student learning outcomes (Gil et al., 2026; Liu & Hallinger, 2026). This perspective is grounded in a growing body of empirical evidence demonstrating that the effects of school leadership on student achievement are predominantly indirect, operating through teachers' instructional behaviors and the organizational conditions that support learning (Day et al., 2016; Kraft et al., 2018). Accordingly, principal leadership is best understood as a multidimensional construct that encompasses a range of practices aimed at improving teaching and learning processes.

From a theoretical standpoint, principal leadership can be categorized into several interrelated models, most notably instructional leadership, transformational leadership, and distributed leadership. Instructional leadership emphasizes the principal's direct involvement in curriculum management, supervision of instruction, and monitoring of student progress. Liu & Hallinger (2026) conceptualizes instructional leadership through three core dimensions: (1) defining the school mission, which includes framing and communicating clear academic goals; (2) managing the instructional program, encompassing supervision, evaluation, and coordination of teaching practices; and (3) promoting a positive school learning climate, which involves protecting instructional time, providing professional development, and maintaining high visibility

in instructional matters. This model underscores the principal's role in aligning organizational resources with pedagogical priorities.

In contrast, transformational leadership focuses on inspiring and motivating teachers to achieve collective goals and to engage in continuous improvement. [Leithwood et al. \(2020\)](#) identify key dimensions of transformational leadership, including setting directions (vision building), developing people (capacity building and professional learning), redesigning the organization (fostering collaborative structures), and improving the instructional program. This model highlights the importance of leadership in shaping teachers' beliefs, commitment, and professional identity, thereby contributing to the development of a strong learning-oriented School Climate ([Yalçın et al., 2025](#)).

Additionally, distributed leadership extends the understanding of leadership beyond the formal role of the principal by emphasizing the shared and collective nature of leadership practices within the school. In this perspective, leadership is enacted through interactions among various actors, including teachers, middle leaders, and professional learning communities. Distributed leadership is particularly relevant in fostering teacher collaboration, as it encourages shared decision-making, collective responsibility, and the co-construction of instructional knowledge.

In the context of deep learning, these leadership models converge in emphasizing the principal's role as a catalyst for instructional transformation. Deep learning, characterized by critical thinking, collaboration, and reflective practice ([Chaudhary & Singh, 2025](#); [Desai et al., 2024](#)), requires leadership that not only sets a clear pedagogical vision but also builds the organizational capacity to sustain innovative teaching practices. Principals are therefore expected to create enabling conditions for professional collaboration, support ongoing teacher learning, and cultivate a school climate that values inquiry, experimentation, and continuous improvement.

In this study, principal leadership is conceptualized as a multidimensional construct that integrates elements of instructional and transformational leadership, with a particular emphasis on its role in fostering teacher collaborative culture and shaping school climate. The theoretical framework posits that principal leadership influences school climate indirectly through the mediation of teacher collaboration, reflecting the organizational pathways through which leadership effects are realized. Specifically, leadership practices such as vision building, instructional support, and capacity development are expected to enhance collaborative interactions among teachers, which in turn contribute to the development of a positive and supportive school climate. By situating principal leadership within this integrated framework, the study provides a comprehensive and contextually grounded understanding of how leadership contributes to deep learning-oriented school improvement.

2.2 Theoretical Model and Hypothesis

Teacher collaboration culture is a central element in improving instructional quality and supporting teachers' professional development. Collaboration enables teachers to exchange knowledge, professional experiences, and effective pedagogical practices, thereby strengthening collective teaching effectiveness ([Rechsteiner et al., 2026](#); [Yan & Peng, 2026](#)). It also contributes to the development of professional learning communities, which provide a sustainable organizational structure for continuous teacher learning and reflective practice ([Liu & Hallinger, 2026](#); [Schnellert et al., 2026](#)).

Empirical studies have shown that teacher collaboration is positively associated with instructional improvement and student learning outcomes (Liu & Hallinger, 2026; Rechsteiner et al., 2026; Salo et al., 2024). In line with this evidence, Hargreaves & O'Connor (2025) concept of *collaborative professionalism* emphasizes that meaningful collaboration should be deep, systematic, and explicitly oriented toward improving classroom practice. From this perspective, school principals play a crucial role in establishing the conditions that enable collaborative cultures to develop, particularly by fostering trust, shared responsibility, professional dialogue, and collective engagement in instructional improvement.

School climate refers to the quality of the social, emotional, and academic environment within a school, which shapes the behaviours, perceptions, and experiences of all members of the school community. A positive school climate is widely recognized as a critical condition for effective schooling because it fosters students' engagement, psychological well-being, sense of belonging, and academic achievement (Benbow et al., 2026; Gil et al., 2026; Hu et al., 2025). Beyond its influence on students, school climate also affects teachers' professional motivation, job satisfaction, instructional commitment, and performance in carrying out teaching responsibilities (Virlia et al., 2026). Thus, school climate should not be understood merely as the atmosphere of the school, but as an organizational condition that enables or constrains the quality of teaching and learning.

Recent scholarship emphasizes that school climate emerges from the dynamic interaction among leadership practices, social relationships, institutional norms, and organizational routines. Thapa & Cohen (2023) argue that school climate is shaped through complex interactions between leadership, interpersonal relationships, and school-level organizational practices. In this regard, principals play a strategic role in developing a positive school climate by establishing clear policies, promoting supportive professional relationships, strengthening trust among teachers and students, and cultivating an organizational culture oriented toward learning improvement. Effective principal leadership can therefore function as a key mechanism through which schools create a safe, inclusive, and academically supportive environment for both teachers and students.

Principal leadership has a direct influence on the development of school climate through the policies, communication patterns, and organizational practices enacted within the school. Effective leadership creates a clear sense of direction, establishes shared expectations, and promotes a supportive professional environment in which teachers and students feel valued, respected, and academically engaged. Prior studies indicate that effective school leadership contributes to the creation of a positive, supportive, and learning-oriented school environment (Leithwood et al., 2024; Liu & Hallinger, 2026). Principals who are able to build constructive relationships with teachers and students are more likely to foster trust, strengthen collaboration, and create conditions that support meaningful teaching and learning. Therefore, principal leadership can be understood as a key organizational driver that shapes the quality of school climate by aligning school policies, interpersonal relationships, and instructional practices toward school improvement. Therefore, the first hypothesis is formulated into:

H1: Principal leadership has a positive effect on school climate.

Principal leadership also plays a critical role in developing a culture of teacher collaboration. Principals who actively support collaboration are more likely to create organizational structures, shared routines, and professional opportunities that enable teachers to work collectively in improving instructional quality. Such leadership may be reflected in the provision of scheduled collaborative time, the facilitation of professional learning communities, the encouragement of

peer observation and reflective dialogue, and the establishment of trust-based professional relationships. In this context, teacher collaboration is not merely an informal exchange among teachers, but an organizational culture shaped by leadership practices that promote shared responsibility for student learning and continuous instructional improvement.

Previous studies have shown that strong and supportive leadership is positively associated with higher levels of teacher collaboration ([Hargreaves & O'Connor, 2025](#); [Rechsteiner et al., 2026](#); [Yan & Peng, 2026](#)). Principals who communicate a clear instructional vision, distribute leadership responsibilities, and encourage professional dialogue can strengthen teachers' willingness to share knowledge, discuss pedagogical challenges, and develop collective solutions. Therefore, principal leadership can be viewed as an important antecedent of teacher collaboration culture because it provides both the structural conditions and the relational climate necessary for sustained collaborative practice. Therefore, the second hypothesis is formulated into:

H2: Principal leadership has a positive effect on teacher collaboration culture.

Teacher collaboration not only contributes to improving instructional quality but also plays an important role in shaping a positive school climate. Intensive professional interaction among teachers can strengthen collegial relationships, mutual trust, shared responsibility, and collective commitment to student learning. When teachers regularly exchange ideas, reflect on instructional practices, and jointly address classroom challenges, they are more likely to develop a supportive professional environment that enhances the overall quality of school life. In this sense, teacher collaboration culture functions as a social and organizational resource that promotes harmonious working relationships and supports the development of a conducive learning environment ([Gil et al., 2026](#); [Hu et al., 2025](#)). Therefore, the third hypothesis is formulated into:

H3: Teacher collaboration culture has a positive effect on school climate.

Within the proposed relationship among the variables, teacher collaboration culture may serve as a mediating mechanism linking principal leadership to school climate. Effective principal leadership does not only influence school climate directly through policies, communication, and organizational practices, but also indirectly by strengthening collaborative norms and professional interactions among teachers. Principals who foster trust, provide opportunities for shared decision-making, and encourage collective professional learning can enhance teacher collaboration, which in turn contributes to a more positive and supportive school climate. This argument is consistent with previous studies suggesting that the effects of leadership on organizational outcomes are often mediated by internal school factors, including collaboration, professional culture, and organizational norms ([Liu & Hallinger, 2026](#); [Özdemir et al., 2023](#)). Therefore, the fourth hypothesis is formulated into:

H4: Teacher collaboration culture mediates the effect of principal leadership on school climate

3. METHODS

3.1 Design

This study adopted a quantitative approach employing an explanatory research design to examine the causal relationships among principal leadership, teacher collaborative culture, and school climate. The use of a quantitative paradigm allows for the systematic measurement of latent constructs and the statistical testing of hypothesized relationships derived from established theoretical frameworks in educational leadership and school effectiveness. The explanatory design is particularly appropriate for this study, as it facilitates the verification of theory-driven

hypotheses and enables the identification of direct and indirect effects among variables within a structured model (Hair et al., 2019, 2022).

Furthermore, this design supports the investigation of mediation mechanisms, specifically the role of teacher collaborative culture as an intervening variable linking principal leadership to school climate. By integrating multiple constructs into a single analytical framework, the study provides a more comprehensive understanding of how leadership practices influence organizational outcomes through underlying social and professional processes. The adoption of this approach also enhances the generalizability and robustness of the findings, as it relies on empirical data and advanced statistical techniques to uncover patterns of relationships among variables. Consequently, the explanatory quantitative design offers a rigorous foundation for examining complex interactions among latent constructs and contributes to the development of evidence-based insights in the field of educational

3.2 Population and Sample

The target population of this study comprised teachers working in public senior high schools (SMA Negeri) in East Java, Indonesia. This population was selected because public senior high schools represent a formal secondary education context in which principal leadership, teacher collaboration, school climate, and deep learning practices are institutionally embedded. Respondents were selected using a multistage sampling procedure to ensure that the sample reflected the diversity of public senior high schools across East Java. First, schools were identified from different districts and municipalities to capture geographical variation across urban, semi-urban, and rural areas. Second, teachers from selected schools were invited to participate in the study based on their active teaching status and direct involvement in school-based instructional activities. This procedure was intended to ensure that the respondents had sufficient experience in observing principal leadership practices, engaging in teacher collaboration, and evaluating the prevailing school climate.

Data were collected through an online survey administered via Google Forms, which enabled broad geographic coverage and efficient data acquisition across different school settings. The survey link was distributed through school networks and teacher coordination channels across public senior high schools in East Java. To strengthen representativeness, responses were obtained from teachers affiliated with schools located in various districts and municipalities, thereby reducing the possibility that the findings reflected only one specific school, region, or local administrative context. The distribution of respondents across multiple schools also allowed the study to capture variation in leadership practices, collaborative cultures, and school climate conditions. Thus, the sample was considered appropriate for examining the proposed structural relationships within a wider secondary school context (see table 1).

A total of 1,726 responses were initially obtained. To ensure the rigor and quality of the dataset, a systematic data screening procedure was conducted prior to analysis. This process included the examination of missing values, detection of univariate and multivariate outliers, identification of invalid response patterns such as straight-lining, and assessment of response consistency. Cases with excessive missing data, extreme or implausible values, or patterned responses indicating low engagement were removed from the dataset.

Following this screening process, 1,206 valid responses were retained for further analysis. The final sample represented teachers from diverse public senior high school contexts across East Java and was therefore considered sufficiently broad to support the generalizability of the findings within the target population. In addition, the final sample size exceeded the minimum

requirements for Partial Least Squares Structural Equation Modeling (PLS-SEM), thereby ensuring adequate statistical power and robustness of the results. The implementation of strict data cleaning procedures further enhanced the internal validity and reliability of the study, providing a sound basis for subsequent measurement and structural model evaluation.

Table 1. Demographic Characteristics of Participants

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	482	39.9
	Female	724	60.1
Age	≤ 30 years	214	17.8
	31–40 years	356	29.5
	41–50 years	389	32.3
	> 50 years	247	20.5
Teaching Experience	≤ 5 years	198	16.4
	6–10 years	276	22.9
	11–20 years	401	33.3
	> 20 years	331	27.4
Educational Qualification	Bachelor's Degree (S1)	842	69.8
	Master's Degree (S2)	354	30.2
Employment Status	Civil Servant (ASN/PNS)	918	76.1
	Non-Civil Servant (Non-ASN)	288	23.9
School Location	Urban	654	54.2
	Suburban	311	25.8
	Rural	241	20.0
Certification Status	Certified Teacher	873	72.4
	Not Yet Certified	333	27.6

3.3 Instruments

The data for this study were collected using a structured questionnaire designed to measure four key constructs: principal leadership, teacher collaborative culture, school climate, and deep learning. All items were measured using a five-point Likert scale ranging from 1 = strongly disagree to 5 = strongly agree. The instrument consisted of 32 items, including 12 items measuring principal leadership, 8 items assessing teacher collaborative culture, and 12 items capturing school climate. The items were adapted from well-established instruments in educational leadership, teacher collaboration, and school effectiveness research. Specifically, the principal leadership items were adapted from prior leadership scales grounded in instructional and transformational leadership frameworks, such as leadership practices related to vision building, instructional supervision, teacher support, and professional capacity development. The teacher collaborative culture items were adapted from instruments measuring professional collaboration, shared instructional practices, collective responsibility, and reflective dialogue among teachers. Meanwhile, school climate items were developed based on established school climate frameworks covering collegial relationships, organizational trust, psychological safety, academic support, and shared norms within the school environment.

The principal leadership construct was operationalized through indicators such as the principal's ability to communicate a clear school vision, provide instructional guidance, support teacher professional development, encourage innovation in teaching, and create conditions for effective learning. Teacher collaborative culture was measured through indicators such as teachers' engagement in joint lesson planning, sharing of teaching materials, peer discussion,

collaborative problem solving, and collective reflection on students' learning progress. School climate was assessed through indicators related to mutual trust among school members, supportive collegial relationships, openness of communication, a safe and respectful learning environment, and institutional support for teaching improvement. These indicators were selected because they represent the organizational and professional conditions assumed to support the implementation of deep learning in schools.

The instrument development and validation process was conducted in several stages. First, relevant constructs and dimensions were identified through a review of theoretical and empirical literature on principal leadership, teacher collaboration, school climate, and deep learning. Second, items were adapted and contextualized to fit the public senior high school context in East Java, Indonesia, while maintaining conceptual consistency with the original instruments. Third, the initial version of the questionnaire was reviewed by three experts in educational leadership, school management, and quantitative research methodology. The experts evaluated the relevance, clarity, cultural appropriateness, and construct representativeness of each item. Items considered ambiguous, overlapping, or insufficiently aligned with the intended constructs were revised to improve content validity.

Prior to the main survey, a pilot study was conducted to examine the psychometric quality of the instrument. Reliability analysis showed satisfactory internal consistency across all dimensions. Cronbach's alpha values for principal leadership ranged from 0.85 to 0.91, for teacher collaborative culture from 0.82 to 0.88, and for school climate from 0.86 to 0.92, all exceeding the recommended threshold of 0.70. Composite reliability values also indicated strong reliability, ranging from 0.87 to 0.93 across the constructs. These results suggest that the items consistently measured their respective latent variables.

The construct validity of the instrument was further evaluated using Partial Least Squares Structural Equation Modeling (PLS-SEM). Convergent validity was confirmed through outer loading values above 0.70 and average variance extracted values exceeding 0.50. Discriminant validity was assessed using the Fornell-Larcker criterion and the heterotrait-monotrait ratio, with all HTMT values below the recommended threshold of 0.85. These validation results indicate that the questionnaire demonstrated adequate reliability, convergent validity, and discriminant validity. Therefore, the instrument was considered suitable for testing the proposed structural relationships among principal leadership, teacher collaborative culture, school climate, and deep learning.

3.4 Data Collection and Analysis

Data were collected using an online survey administered via Google Forms to public senior high school teachers in East Java, Indonesia. The use of an online platform enabled efficient distribution across geographically diverse regions and facilitated broad participation. Prior to the main data collection, the instrument was pilot-tested to ensure clarity, reliability, and content validity. Ethical considerations were strictly observed, including voluntary participation, anonymity, and confidentiality of respondents' information. Participants were informed about the purpose of the study and provided consent before completing the questionnaire.

Following data collection, a rigorous data screening procedure was conducted to ensure the quality and integrity of the dataset. This included checking for missing values, identifying univariate and multivariate outliers, detecting response patterns indicative of low engagement (e.g., straight-lining), and assessing overall response consistency. Only responses that met the established quality criteria were retained for further analysis, thereby enhancing the validity and

reliability of the results. Data analysis was performed using Partial Least Squares Structural Equation Modeling (PLS-SEM) with SmartPLS 4. The analysis followed a two-step approach consisting of measurement model (outer model) evaluation and structural model (inner model) assessment, in line with recommended guidelines (Hair et al., 2019, 2022).

The evaluation of the measurement model focused on assessing the reliability and validity of the constructs. Convergent validity was examined through outer loadings and the average variance extracted (AVE), with acceptable thresholds set at outer loadings above 0.60 and AVE values greater than 0.50. Outer loading values exceeding 0.60 were considered acceptable, particularly in exploratory research contexts. Discriminant validity was assessed using multiple criteria, including the Fornell–Larcker criterion, cross-loadings, and the heterotrait–monotrait ratio (HTMT), with HTMT values below 0.90 indicating adequate discriminant validity. Construct reliability was evaluated using Cronbach’s alpha and composite reliability (CR), with values above 0.70 indicating satisfactory internal consistency.

The structural model evaluation aimed to examine the relationships among latent variables and the predictive capability of the model. This included assessing the coefficient of determination (R^2) to determine the explanatory power of the endogenous constructs, as well as predictive relevance (Q^2) to evaluate the model’s predictive accuracy. Effect size (f^2) was calculated to determine the magnitude of the impact of exogenous variables on endogenous constructs. Additionally, multicollinearity was assessed using the variance inflation factor (VIF), with values below 5 indicating the absence of multicollinearity issues. Hypothesis testing was conducted using a bootstrapping procedure to estimate the significance of path coefficients. This approach generated standardized path coefficients (β), t-statistics, and p-values for each hypothesized relationship. A hypothesis was considered statistically significant if the p-value was less than 0.05.

Furthermore, mediation analysis was performed to examine the role of teacher collaborative culture as an intervening variable in the relationship between principal leadership and school climate. The indirect effect was assessed using the bootstrapping method, and mediation was considered significant when the indirect path coefficient was statistically significant ($p < 0.05$). The nature of mediation (partial or full) was determined by examining both direct and indirect effects within the structural model.

4. RESULT AND DISCUSSION

4.1 Result

The following is a descriptive analysis, as shown in Table 2.

Table 2. Descriptive Analysis

Variable	Mean	Median	Min	Max	Std. Deviation
Principal Leadership	4,59	5,00	1	5	0,59
Teacher Collaboration Culture	4,46	5,00	1	5	0,59
School Climate	4,57	5,00	1	5	0,58

Table 2 indicates that all research variables fall within the high category (mean > 4.00 on a 1–5 Likert scale). The principal leadership variable demonstrates the highest mean score ($M = 4.59$), followed by school climate ($M = 4.57$) and teacher collaboration culture ($M = 4.46$). The median values for all variables are 5, suggesting that the majority of respondents provided highly positive evaluations. The relatively small standard deviations (± 0.58 – 0.59) indicate low variability in responses, reflecting a high degree of homogeneity. This finding suggests consistent perceptions

among teachers regarding principal leadership, collaborative culture, and school climate within senior high schools. The following are the results of the outer loadings analysis, as shown in Table 3.

Table 3. The Results of Outer Loadings Analysis

Indicator	Outer Loadings
M01 <- Teacher collaboration Culture	0,703
M02 <- Teacher collaboration Culture	0,611
M03 <- Teacher collaboration Culture	0,743
M04 <- Teacher collaboration Culture	0,766
M05 <- Teacher collaboration Culture	0,712
M06 <- Teacher collaboration Culture	0,783
M07 <- Teacher collaboration Culture	0,681
M08 <- Teacher collaboration Culture	0,681
Y01 <- School Climate	0,772
Y02 <- School Climate	0,769
Y03 <- School Climate	0,795
Y04 <- School Climate	0,679
Y05 <- School Climate	0,659
Y06 <- School Climate	0,720
Y07 <- School Climate	0,742
Y08 <- School Climate	0,737
Y09 <- School Climate	0,776
Y10 <- School Climate	0,750
Y11 <- School Climate	0,799
Y12 <- School Climate	0,716
x01 <- Principal Leadership	0,661
x02 <- Principal Leadership	0,682
x03 <- Principal Leadership	0,628
x04 <- Principal Leadership	0,628
x05 <- Principal Leadership	0,742
x06 <- Principal Leadership	0,768
x07 <- Principal Leadership	0,741
x08 <- Principal Leadership	0,728
x09 <- Principal Leadership	0,644
x10 <- Principal Leadership	0,764
x11 <- Principal Leadership	0,744
x12 <- Principal Leadership	0,802

Based on the outer loading results presented in Table 3, all indicators exhibit loading values above the threshold of 0.60. The loadings range from 0.611 to 0.802, indicating that all indicators are considered valid in adequately reflecting their respective constructs. The following is the Fornell-Larcker analysis, as shown in Table 4.

Table 4. Analysis of Fornell-Larcker

Construct	BK	IK	KS
Teacher collaboration Culture	0,712		
School Climate	0,794	0,744	
Principal Leadership	0,685	0,787	0,713

Based on the Fornell–Larcker criterion, the square root of the Average Variance Extracted (AVE) for each construct exceeds its correlations with other constructs, indicating that discriminant validity has been established. The following is an analysis of cross loadings, as shown in Table 5.

Table 5. Analysis of Cross Loadings

Indicator	BK	IK	KS
M01	0,703	0,511	0,451
M02	0,611	0,472	0,406
M03	0,743	0,521	0,455
M04	0,766	0,593	0,478
M05	0,712	0,518	0,406
M06	0,783	0,692	0,682
M07	0,681	0,538	0,426
M08	0,681	0,621	0,518
Y01	0,567	0,77	0,676
Y02	0,564	0,769	0,657
Y03	0,578	0,795	0,710
Y04	0,652	0,679	0,460
Y05	0,594	0,659	0,432
Y06	0,659	0,720	0,505
Y07	0,578	0,742	0,599
Y08	0,533	0,737	0,567
Y09	0,594	0,776	0,593
Y10	0,595	0,750	0,594
Y11	0,656	0,799	0,606
Y12	0,528	0,716	0,590
x01	0,368	0,443	0,661
x02	0,461	0,524	0,682
x03	0,396	0,448	0,628
x04	0,424	0,471	0,628
x05	0,514	0,550	0,742
x06	0,566	0,606	0,768
x07	0,519	0,591	0,741
x08	0,503	0,615	0,728
x09	0,418	0,510	0,644
x10	0,506	0,611	0,764
x11	0,485	0,605	0,744
x12	0,630	0,689	0,802

The cross-loading results also show that each indicator has the highest loading value on the construct it is measuring, compared to other constructs, thus meeting the criteria for discriminant validity. The following is the Heterotrait-Monotrait Ratio (HTMT), as shown in Table 6.

Table 6. Heterotrait-Monotrait Ratio (HTMT)

Variable	Heterotrait-Monotrait Ratio (HTMT)
School Climate <-> Teacher collaboration Culture	0,842
Principal Leadership <-> Teacher collaboration Culture	0,751
Principal Leadership <-> School Climate	0,846

In addition, the results of the HTMT test in Table 6 show that the HTMT values between variables range from 0.751 to 0.846, all of which are below the threshold of 0.90. This indicates that each construct in the model can be empirically distinguished. The following shows the Average Variance Extracted (AVE), as shown in Table 7.

Table 7. Average Variance Extracted (AVE)

Variable	Average (AVE)
Teacher collaboration Culture	0,507
School Climate	0,554
Principal Leadership	0,509

The AVE values in Table 7 indicate that all constructs have values above 0.50. Therefore, all constructs meet the criteria for convergent validity. The following are the composite reliability and cronbach's alpha, as shown in Table 8.

Table 8. Composite Reliability and Cronbach Alpha

Variable	Cronbach's Alpha	Composite Reliability
Teacher collaboration Culture	0,860	0,891
School Climate	0,926	0,937
Principal Leadership	0,911	0,925

The Cronbach's Alpha values for teacher collaboration culture are 0.860, for school climate are 0.926, and for principal leadership are 0.911. The Composite Reliability values for each construct are 0.891, 0.937, and 0.925, respectively, indicating that all constructs exhibit excellent internal consistency. The following are the determinant, coefficient, and R-squared values, as shown in Table 9.

Table 9. Determinant Coefficient R Square

Variable	R-square	R-square adjusted
Teacher Collaboration Culture	0,469	0,469
School Climate	0,742	0,742

Based on the analysis results in Table 9, the R^2 value of 0.469 indicates that 46.9% of the variation in teacher collaboration culture is explained by principal leadership. Meanwhile, the R^2 value of 0.742 shows that 74.2% of the variation in school climate is explained by principal leadership and teacher collaboration. The following is the effect size (F-square), as shown in Table 10.

Table 10. Effect Size of F square

Variable	F-square
Teacher Collaboration Culture -> School Climate	0,476
Principal Leadership -> Teacher Collaboration Culture	0,885
Principal Leadership -> School Climate	0,430

The f^2 values indicate that all relationships have a strong effect ($f^2 > 0.35$), suggesting a substantial contribution between the variables in the model. The following are the VIF values for multicollinearity, as shown in Table 11.

Table 11. Multicollinearities of VIF

Variable	VIF
Teacher Collaboration Culture -> School Climate	1,885
Principal Leadership -> Teacher Collaboration Culture	1,000
Principal Leadership -> School Climate	1,885

The VIF values for all variables are below 5 (ranging from 1.000 to 1.885), indicating that there are no issues with multicollinearity. The following are the PLS-SEM structural model and hypothesis testing results, as shown in Figure 1.

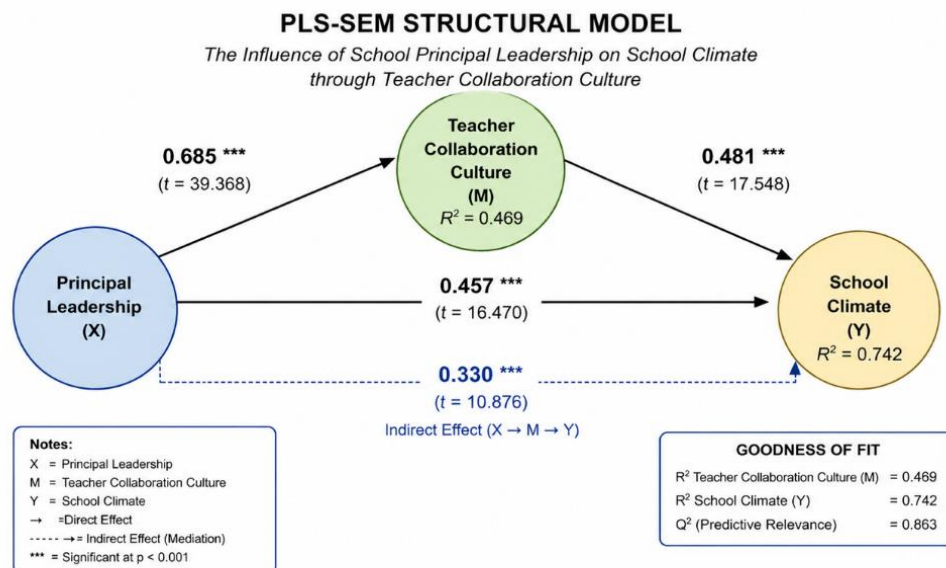


Figure 1. PLS-SEM Structural Model and Hypothesis Testing Results
Source: Output SmartPLS 4.0 (processed, 2025)

Figure 1. PLS-SEM Structural Model and Hypothesis Testing Results

Figure 1 shows that the path from leadership to teacher collaboration culture has the largest coefficient in the model. The following are the indirect impacts, as shown in Table 12 and Table 13.

Table 12. Indirect Impact

Direct Impact	Coefficient (β)	t-statistic	p-value	Results
Teacher Collaboration Culture -> School Climate	0,481	17,548	< 0,001	Positive
Principal Leadership -> Teacher Collaboration Culture	0,685	39,368	< 0,001	Positive
Principal Leadership -> School Climate	0,457	16,470	< 0,001	Positive

Table 13. Indirect impact

Indirect Impact	Coefficient (β)	t-statistic	p-value	Results
Principal Leadership -> Teacher Collaboration Culture -> School Climate	0,330	16,588	< 0,001	Mediating

The results indicate that teacher collaboration culture acts as a partial mediator in the relationship between principal leadership and school climate.

4.2 Discussion

This study reaffirms that principal leadership plays a significant role in shaping school climate, both directly and indirectly through teacher collaboration culture. More importantly, the findings suggest that the influence of leadership on school climate cannot be understood merely as the outcome of individual leadership competence, authority, or administrative control. Rather, leadership becomes meaningful when it is able to activate relational, instructional, and organizational processes within the school. This finding is theoretically important because it supports the view that schools are not only formal bureaucratic institutions but also social learning organizations in which climate is constructed through repeated interactions, shared norms, professional trust, and collective practices. Therefore, the quality of school climate depends not only on what principals decide or communicate, but also on how teachers internalize, enact, and sustain those leadership directions through collaborative professional work.

The significant direct effect of principal leadership on school climate indicates that leadership practices oriented toward learning can create a supportive, orderly, and academically focused school environment. Principals who articulate a clear instructional vision, provide professional support, encourage innovation, and maintain constructive communication are more likely to build trust, shared commitment, and a sense of organizational direction among teachers. This result is consistent with the instructional leadership framework, which positions principals as key agents in strengthening the organizational conditions required for effective teaching and learning (Leithwood et al., 2020; Ma & Marion, 2024). From this perspective, leadership contributes to school climate by shaping teachers' perceptions of institutional support, fairness, professional expectations, and the school's collective learning orientation. The finding also resonates with transformational leadership theory, which emphasizes that leaders influence organizational members by inspiring shared goals, developing professional capacity, and fostering commitment to collective improvement.

However, the stronger and more substantive contribution of the indirect pathway through teacher collaboration culture indicates that leadership alone is insufficient to produce a positive school climate unless it is translated into collaborative professional practices. This finding provides a critical refinement to leadership theory by showing that the effect of principal

leadership is not purely linear or top-down. Instead, it operates through distributed and socially mediated processes among teachers. In other words, leadership creates the conditions for collaboration, but teacher collaboration becomes the mechanism through which these conditions are transformed into a lived school climate. This explains why schools with similar leadership structures may experience different climates: leadership messages and policies become influential only when they are embedded in teachers' daily interactions, joint lesson planning, peer learning, collective problem-solving, and shared reflection on instructional improvement.

The mediating role of teacher collaboration culture is particularly important because school climate is fundamentally relational. A positive climate is not produced only by formal rules, administrative supervision, or school facilities, but by the quality of professional relationships and the degree to which teachers feel supported, trusted, and collectively responsible for student learning. When teachers collaborate regularly, they develop shared pedagogical language, reduce professional isolation, and build mutual accountability. These processes strengthen collegial trust, openness, and psychological safety, which are central elements of school climate. Thus, the finding supports previous studies showing that teacher collaboration is a major factor in improving instructional quality, organizational trust, and school climate (Gil et al., 2026; Hargreaves & O'Connor, 2025; Hu et al., 2025; Rechsteiner et al., 2026; Yan & Peng, 2026). The present study extends those findings by demonstrating that collaboration does not merely function as an independent predictor of school improvement, but also serves as a mediating mechanism that explains how leadership is converted into a more supportive school environment.

The findings are also aligned with recent leadership research suggesting that school leadership affects organizational outcomes through professional collaboration and collective capacity building (Leithwood et al., 2024; Liu & Hallinger, 2026; Özdemir et al., 2023). Similar to these studies, the present research confirms that effective leadership is not limited to supervision, evaluation, or managerial coordination. Instead, effective leadership involves creating structures and cultures that allow teachers to learn from one another, share expertise, and engage in sustained professional inquiry. Nevertheless, this study differs from prior research that primarily emphasized direct associations between leadership and school climate. By testing teacher collaboration as a mediating variable, this study provides a more nuanced explanation of the leadership–climate relationship. It shows that the pathway from leadership to school climate is not only administrative but also professional and collaborative.

Another important contribution of the findings is the high coefficient of determination for school climate, which indicates that principal leadership and teacher collaboration culture together have strong explanatory power in predicting the quality of the school environment. This result suggests that school climate is shaped by the interaction between leadership direction and teacher-level professional culture. Leadership provides vision, expectations, resources, and institutional support, while collaboration provides the social and pedagogical process through which these elements become part of teachers' daily professional experience. This interpretation is consistent with ecological and organizational perspectives on school climate, which argue that climate emerges from the interaction between leadership, social relationships, norms, and organizational practices (Sakız et al., 2026; Yalçın et al., 2025; Thapa & Cohen, 2023). Therefore, improving school climate requires more than strengthening principal leadership alone; it also requires building collaborative routines and professional communities that sustain positive organizational relationships.

From a deep learning perspective, the findings provide further evidence that teacher collaboration is a critical prerequisite for implementing learning that promotes higher-order thinking, inquiry, creativity, reflection, and meaningful knowledge construction. Deep learning requires teachers to design authentic tasks, integrate interdisciplinary ideas, encourage student agency, and use assessment practices that go beyond factual recall. Such practices are difficult to implement when teachers work individually or when school climate does not support experimentation and professional dialogue. A supportive school climate creates psychological safety for innovation, while teacher collaboration enables teachers to jointly design, test, evaluate, and refine deep learning-oriented pedagogies. Thus, leadership becomes effective for deep learning when it strengthens teachers' collective capacity rather than merely demanding instructional change (Chaudhary & Singh, 2025; Desai et al., 2024).

These findings are similar to previous studies that emphasized the importance of instructional leadership and collaborative professional culture in improving school effectiveness. However, they differ from studies that treat leadership as the dominant determinant of school improvement. The present findings suggest that leadership influence is conditional upon the existence of collaborative professional culture. In contexts where collaboration is weak, leadership may remain symbolic, procedural, or dependent on individual compliance. Conversely, when collaboration is strong, leadership is more likely to produce sustainable improvement because teachers collectively interpret, adapt, and enact school goals. This distinction is important because it shifts the discussion from leader-centered effectiveness to organization-centered improvement.

Overall, the study confirms that principal leadership, teacher collaboration culture, and school climate are mutually reinforcing components of school improvement. Principal leadership establishes the strategic and instructional direction of the school, teacher collaboration translates this direction into shared professional action, and school climate reflects the quality of the organizational environment produced through these interactions. The findings therefore imply that efforts to strengthen deep learning should not focus only on curriculum reform or teacher training at the individual level. Instead, schools need leadership practices that deliberately cultivate collaborative teacher cultures and supportive climates. Such an integrated approach is more likely to sustain deep learning practices because it connects leadership vision, teacher professionalism, and organizational conditions into a coherent process of educational improvement.

5. CONCLUSION

This study examined the relationship between principal leadership, teacher collaboration, and school climate, with particular attention to the mediating role of teacher collaboration. The findings answered the research questions and supported the proposed hypotheses by showing that principal leadership had a significant positive effect on school climate and teacher collaboration. In addition, teacher collaboration was found to have a significant positive effect on school climate and served as an important mediating mechanism in the relationship between principal leadership and school climate. These results indicate that leadership does not influence school climate only through direct administrative or instructional actions, but also through its capacity to foster collaborative professional practices among teachers. Therefore, the study confirms that teacher collaboration is a key organizational pathway through which principal leadership is translated into a more supportive, trustful, and learning-oriented school climate.

The findings offer important theoretical, practical, and policy implications by demonstrating that principal leadership influences school climate both directly and indirectly through teacher collaboration, thereby confirming that school improvement is not merely leader-centered but socially mediated through teachers' collective professional culture. Practically, principals should adopt learning-centered and collaborative leadership by fostering shared vision, professional trust, collegial interaction, joint lesson planning, peer discussion, and reflective practice. At the policy level, leadership development programs should strengthen principals' capacity to build collaborative cultures, support professional learning communities, and position school climate as a key indicator of educational quality and deep learning implementation. Despite these contributions, this study has several limitations. First, the use of a cross-sectional research design limits the ability to establish causal and long-term relationships among principal leadership, teacher collaboration, and school climate. Although the structural model provides evidence of significant associations among variables, it cannot fully explain how these relationships develop over time. Second, the study relied on perception-based questionnaire data, which may involve subjective bias, social desirability bias, or common method bias. Although validity and reliability procedures were conducted to reduce these limitations, future research may benefit from incorporating multiple data sources. Third, the research model focused only on principal leadership, teacher collaboration, and school climate, while other relevant organizational and psychological variables were not included.

Future studies are therefore recommended to employ longitudinal designs to examine how principal leadership and teacher collaboration influence school climate over different time periods. A longitudinal approach would allow researchers to identify developmental patterns, causal direction, and the sustainability of leadership effects on school improvement. Future research could also use mixed-methods designs by combining survey data with interviews, classroom observations, document analysis, or focus group discussions to obtain richer explanations of how collaboration is enacted in daily school practices. In addition, future studies should expand the research model by including other theoretically relevant variables, such as organizational trust, collective teacher efficacy, teacher commitment, professional learning community practices, instructional innovation, and teacher well-being.

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