



# **Proceedings of International Conference on Multidisciplinary Research: Innovation, Healthcare, Education for Viksit Bharat (ICMR-2026)**



**1**

## **Editors**

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## Chapter 23: Teacher Leadership and School Improvement in Contemporary Educational Institutions

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**Abstract—** Contemporary educational institutions increasingly require leadership practices that extend beyond formal administrative positions and mobilize teachers as active agents of institutional improvement. This study investigates teacher leadership as a multidimensional mechanism connecting professional collaboration, instructional innovation, digital decision-making, and school-improvement capacity. A distinctive research gap is identified in the limited integration of teacher leadership indicators with data-driven and computational approaches capable of explaining variation in school improvement outcomes. The proposed research conceptualizes teacher leadership through instructional influence, collaborative decision-making, professional knowledge sharing, digital leadership competence, and participation in organizational change. School improvement is correspondingly examined through instructional quality, professional learning, organizational adaptability, student-support capacity, and evidence-informed decision-making. The study proposes an interpretable machine-learning framework for identifying nonlinear relationships between leadership attributes and institutional improvement indicators rather than relying exclusively on conventional linear associations. Particular attention is given to the mediating contribution of professional learning communities and the moderating role of organizational support and digital readiness. The resulting framework is intended to provide a theoretically grounded and analytically transparent approach for identifying leadership practices that contribute most strongly to sustainable improvement in contemporary schools.

**Keywords:** Teacher Leadership; School Improvement; Distributed Leadership; Professional Learning Communities; Digital Leadership; Educational Analytics

### Introduction

Educational leadership has traditionally been associated with principals, administrators, department heads, and other formally designated office holders. Contemporary educational institutions, however, operate within environments characterized by rapid curriculum change, expanding digital infrastructure, increasingly heterogeneous student populations, evidence-based accountability requirements, and continuing demands for professional innovation. Under such conditions, concentrating leadership responsibility within a small administrative group can restrict organizational learning and reduce the capacity of schools to respond quickly to emerging instructional problems. Teacher leadership has consequently gained importance as an alternative and complementary model

in which teachers influence educational practices beyond the boundaries of their individual classrooms.

Teacher leadership may be understood as the capacity of teachers to exercise professional influence over instructional practices, curriculum development, collaborative learning, organizational decision-making, mentoring, innovation, and school reform without necessarily occupying a formal managerial position. Its significance lies in the proximity of teachers to the instructional core of schooling. Teachers continuously interpret curriculum expectations, observe student learning patterns, evaluate instructional strategies, communicate with families, collaborate with colleagues, and encounter the practical consequences of educational policies. Their professional knowledge therefore represents an important institutional resource for improvement.

The relevance of teacher leadership has become more pronounced since the substantial disruption experienced by educational systems during and after the COVID-19 period. Schools were required to reorganize teaching practices, implement online and hybrid instructional systems, address learning discontinuities, develop new digital competences, and reconsider conventional approaches to professional collaboration. These developments strengthened the argument that improvement cannot depend exclusively on top-down administrative directives. Teachers increasingly became curriculum adapters, technology facilitators, peer trainers, instructional mentors, data interpreters, and coordinators of local solutions.

The digital transformation of schooling has further expanded the scope of teacher leadership. Contemporary teachers are frequently expected to use learning-management systems, digital assessment platforms, student-performance dashboards, collaborative applications, artificial intelligence-supported educational technologies, and learning analytics. The OECD Digital Education Outlook 2023 identifies teachers as critical actors in educational digital transformation and emphasizes teacher agency, professional collaboration, leadership, and continuous professional learning as necessary components of effective digital ecosystems. This shift suggests that teacher leadership should no longer be examined only through traditional activities such as mentoring colleagues or participating in school committees. Digital competence, responsible technology adoption, evidence interpretation, and participation in technology-related decision-making have become additional dimensions of contemporary teacher influence.

School improvement represents an equally complex construct. Improvement cannot be reduced to short-term examination performance. A sustainable school-improvement process

involves strengthening instructional practices, professional capacity, organizational culture, collaboration, learner support, curriculum responsiveness, technology integration, and the ability of the institution to learn from evidence. Improvement therefore emerges through coordinated changes across several interdependent organizational dimensions.

Teacher leadership potentially contributes to these dimensions through multiple pathways. Teachers who lead professional discussions can facilitate the diffusion of effective instructional practices. Teachers participating in curriculum decisions can improve alignment between policy expectations and classroom realities. Peer mentoring can accelerate professional learning among less experienced educators. Teacher-led inquiry can help schools identify instructional weaknesses, while teachers with strong digital competence may facilitate effective adoption of educational technologies. Leadership distributed among teachers may also strengthen collective responsibility because organizational improvement becomes a shared professional objective rather than exclusively an administrative responsibility.

Nevertheless, the relationship between teacher leadership and school improvement is unlikely to be uniform. Merely allocating additional responsibilities to teachers does not necessarily produce meaningful leadership. Teachers may participate in committees without having substantial decision-making authority. Leadership roles may become symbolic if administrators retain complete control over educational priorities. Similarly, excessive responsibilities can increase workload without improving professional autonomy. Organizational culture, trust, administrative support, resource availability, professional learning opportunities, and communication structures therefore determine whether teacher leadership becomes genuinely influential.

Professional learning communities provide an important organizational mechanism through which teacher leadership may influence school improvement. A professional learning community encourages teachers to examine teaching practices collectively, share professional knowledge, interpret evidence, experiment with instructional strategies, and assume collective responsibility for learner development. Recent empirical research has continued to identify connections between supportive and shared leadership, professional learning communities, and teacher efficacy. For example, Yidana and Acquah's 2024 study of senior high-school Economics teachers found that shared and supportive leadership within professional learning communities was significantly related to teaching efficacy, while other dimensions of collective professional practice also demonstrated positive relationships. Such evidence supports the proposition that leadership becomes more consequential when embedded within collaborative professional structures.

Despite growing research on distributed leadership, professional learning communities, instructional leadership, and teacher agency, an important methodological gap remains. A considerable proportion of existing studies employ descriptive surveys, correlations, regression models, interviews, or

structural equation modelling. These methodologies have made significant contributions to educational leadership research; however, conventional linear models may inadequately capture complex interactions among leadership practices, school climate, organizational support, professional collaboration, digital readiness, and improvement outcomes. Teacher leadership may produce different outcomes under different combinations of institutional conditions, indicating the possibility of nonlinear and conditional relationships.

A second gap concerns the fragmented treatment of leadership dimensions. Previous investigations frequently examine teacher leadership, professional learning communities, teacher efficacy, digital competence, or school improvement independently. Fewer studies integrate these factors into a unified analytical structure. This fragmentation makes it difficult to determine whether instructional leadership behavior, peer collaboration, decision-making participation, digital leadership, mentoring, or innovation-oriented leadership contributes most strongly to school improvement.

A third limitation concerns interpretability. Predictive analytics and machine-learning techniques are increasingly used in educational research, but a purely predictive model provides limited practical value if school leaders cannot understand why particular improvement outcomes are predicted. Consequently, contemporary educational analytics requires models capable of combining predictive performance with explanatory transparency.

The present study addresses these limitations by conceptualizing teacher leadership as a multidimensional institutional capacity and proposing an interpretable machine-learning framework for examining its relationship with school improvement. Rather than treating teachers simply as respondents reporting leadership perceptions, the proposed framework models leadership through multiple measurable dimensions including instructional influence, collaborative decision-making, professional knowledge sharing, mentoring, digital leadership competence, innovation orientation, and participation in organizational improvement activities.

The central research objective is therefore to determine how different configurations of teacher leadership contribute to school-improvement capacity and to identify the organizational conditions under which this relationship becomes stronger or weaker. The study further investigates whether professional learning-community participation functions as an intermediary mechanism and whether institutional support and digital readiness influence the effectiveness of teacher leadership.

The proposed research is guided by three related questions: which dimensions of teacher leadership provide the greatest explanatory contribution to school improvement; whether combinations of leadership attributes produce nonlinear improvement effects; and whether interpretable machine-learning techniques can identify meaningful leadership profiles that conventional statistical approaches may overlook.

By addressing these questions, the research attempts to connect educational leadership theory with contemporary analytical methods without reducing school leadership to an algorithmic

phenomenon. Machine learning is employed as an analytical instrument rather than as a substitute for educational judgement. The conceptual emphasis remains on understanding how professional agency, organizational conditions, collaboration, and evidence-informed practice interact in contemporary educational institutions.

## **Literature Review**

### **2.1 Conceptual Evolution of Teacher Leadership**

Teacher leadership emerged partly from dissatisfaction with strongly hierarchical models of school administration. Traditional organizational structures generally positioned principals as primary decision-makers and teachers as implementers of administratively determined policies. Distributed and participatory perspectives challenged this separation by arguing that professional expertise exists throughout educational organizations.

Within this perspective, leadership is distinguished from formal authority. A teacher can exercise meaningful leadership by influencing curriculum design, helping colleagues improve instructional practice, coordinating professional learning, introducing innovative teaching strategies, mentoring newly appointed educators, interpreting student-performance evidence, or facilitating collaborative problem solving. Teacher leadership therefore represents professional influence rather than merely positional status.

Contemporary conceptualizations further differentiate teacher leadership from administrative delegation. Delegation occurs when administrators assign tasks to teachers while retaining principal control. Genuine teacher leadership requires some combination of autonomy, professional influence, access to decision-making, shared responsibility, and recognition of teacher expertise. This distinction is particularly important because schools may formally describe leadership as distributed while operational practice remains strongly centralized.

Teacher leadership can therefore be examined across several domains. Instructional leadership concerns influence over pedagogy, assessment, curriculum, and learning design. Professional leadership involves mentoring, peer learning, and collaborative knowledge creation. Organizational leadership concerns participation in institutional decisions and improvement planning. Innovation leadership relates to experimentation with emerging instructional practices. Digital teacher leadership includes responsible integration of digital technologies, support for colleagues, interpretation of educational data, and participation in technology-related decision-making.

### **2.2 Distributed Leadership and Organizational Capacity**

Distributed leadership provides an important theoretical foundation for understanding teacher leadership because it conceptualizes leadership as an organizational practice involving interactions among multiple actors rather than as the behavioral characteristics of one formal leader. Within educational institutions, expertise may be distributed among administrators, senior teachers, subject specialists, technology coordinators, counselors, and classroom educators.

The potential advantage of distributed leadership is its capacity to expand institutional problem-solving resources. School administrators cannot possess detailed expertise in every subject area, pedagogical challenge, technological application, or learner-support issue. Leadership distribution enables decisions to incorporate specialized professional knowledge.

However, distributed leadership should not automatically be interpreted as democratic or effective leadership. Distribution can become dysfunctional when roles are ambiguous, accountability is unclear, communication is inadequate, or leadership responsibilities are assigned without corresponding authority and resources. Consequently, the present research treats organizational support as a critical contextual variable rather than assuming that greater leadership participation inevitably produces better institutional outcomes.

Psychological safety and professional trust are particularly important. Teachers are unlikely to challenge ineffective practices or recommend innovations when organizational cultures penalize professional disagreement. Conversely, environments that encourage professional dialogue can transform teacher expertise into collective institutional knowledge.

### **2.3 Teacher Leadership and Professional Learning Communities**

Professional learning communities represent one of the principal environments through which teacher leadership becomes operational. Effective professional learning communities emphasize collaborative inquiry rather than passive participation in occasional training sessions. Teachers collectively identify learning problems, analyze instructional evidence, share practices, observe professional performance, discuss learner needs, and evaluate alternative interventions.

The relationship between teacher leadership and professional learning communities is reciprocal. Teacher leadership can strengthen professional learning communities because influential teachers coordinate professional discussion and mobilize peer expertise. At the same time, professional learning communities provide opportunities in which teachers develop leadership competence.

Research published during the contemporary period continues to demonstrate associations among collaborative professional cultures, supportive leadership, professional learning, and teacher-related outcomes. Yidana and Acquah (2024), using structural equation modelling, reported that shared and supportive leadership within professional learning communities had a significant influence on teaching efficacy among Economics teachers. Conceptual work published in 2024 has similarly emphasized the role of professional learning communities and school leadership in promoting collaborative professional development.

These findings indicate that teacher leadership is unlikely to operate effectively through isolated individual action. Collective structures transform individual expertise into organizational capability. Accordingly, professional learning-community participation is conceptualized in this study as a possible

mediating mechanism between teacher leadership and school improvement.

#### 2.4 Teacher Leadership and Instructional Improvement

The strongest theoretical justification for teacher leadership concerns its proximity to classroom instruction. Teachers possess practical knowledge about learner difficulties, curriculum implementation, classroom interaction, assessment design, and instructional adaptation. When this knowledge is confined to individual classrooms, institutional learning remains limited. Teacher leadership provides mechanisms for transferring successful instructional knowledge across departments and classrooms.

Instructional influence may occur through peer observation, mentoring, collaborative lesson planning, assessment moderation, curriculum coordination, action research, and professional dialogue. These activities can promote instructional consistency while allowing teachers to preserve context-sensitive professional judgement.

Importantly, instructional leadership undertaken by teachers does not imply complete standardization of pedagogy. Improvement depends partly on teachers' ability to evaluate which practices are appropriate for specific learner populations. Teacher leadership therefore requires a balance between organizational coherence and professional discretion.

#### 2.5 Digital Transformation and Emerging Forms of Teacher Leadership

Digitalization has altered the organizational environment in which teacher leadership operates. Contemporary schools increasingly use digital platforms for teaching, assessment, administration, professional communication, and learner monitoring. Artificial intelligence and learning analytics are further extending the range of technologies available for educational decision support.

The OECD has emphasized that teachers remain central to effective digital transformation and that professional agency, collaboration, leadership, continuous learning, and participation in the development of digital ecosystems are important conditions for productive technology integration. Digital teacher leadership therefore extends beyond technical proficiency. It includes the ability to evaluate technological appropriateness, support colleagues, interpret data responsibly, recognize ethical implications, protect learner interests, and align technological adoption with pedagogical objectives.

This emerging form of leadership introduces an additional research problem. A teacher may demonstrate strong conventional instructional leadership but possess limited capacity to lead digitally mediated improvement. Conversely, technologically skilled teachers may lack organizational influence. Measuring these dimensions separately may therefore reveal leadership profiles that are hidden when teacher leadership is represented by a single composite score.

#### 2.6 Data-Informed Decision-Making and School Improvement

Contemporary improvement systems increasingly generate substantial amounts of educational data, including assessment records, attendance information, learning-management-system

activity, intervention records, teacher surveys, and institutional indicators. Data availability creates opportunities for evidence-informed leadership but does not automatically result in effective decisions.

Teachers need sufficient data literacy to distinguish meaningful patterns from superficial numerical differences. Leadership is therefore necessary for converting data into professional inquiry. Teacher leaders may facilitate collaborative interpretation of learner performance, identify areas requiring intervention, communicate evidence to colleagues, and evaluate whether implemented strategies produce improvement.

The use of learning analytics and predictive models introduces further possibilities but also methodological and ethical responsibilities. Prediction alone cannot establish educational causality. Furthermore, complex black-box systems may provide recommendations without explaining the underlying decision process. For institutional leadership research, model interpretability is particularly important because recommendations must remain understandable to educators.

The present study consequently proposes the use of interpretable machine-learning techniques capable of identifying feature importance and nonlinear interactions while retaining meaningful links with educational constructs.

#### Proposed Methodology

The proposed study adopts a quantitative, explanatory-predictive design to examine how different dimensions of teacher leadership contribute to school-improvement capacity in contemporary educational institutions. Unlike conventional leadership studies that depend primarily on mean comparisons or linear regression, the present design combines psychometric measurement, multivariate statistical analysis, and interpretable machine-learning modelling. The purpose is not merely to predict school-improvement scores, but to determine which combinations of teacher-leadership characteristics are most influential and whether nonlinear interactions exist among leadership, collaboration, digital readiness, and organizational support.

The analytical framework is based on four interconnected construct groups. The first represents **teacher leadership**, measured through instructional influence, collaborative decision-making, peer mentoring, professional knowledge sharing, innovation orientation, and digital leadership competence. The second represents **organizational conditions**, including principal support, decision-making autonomy, psychological safety, technological infrastructure, and access to professional-development resources. The third captures **professional learning-community engagement**, including collaborative inquiry, collective problem solving, reflective dialogue, and shared responsibility for teaching quality. The fourth represents **school-improvement capacity**, operationalized through perceived instructional improvement, organizational adaptability, evidence-informed decision-making, professional-learning effectiveness, and student-support responsiveness.

A multistage sampling strategy is proposed. Schools are first stratified according to management type, institutional level, and

geographic setting. Teachers are subsequently selected from participating institutions using proportionate sampling to obtain adequate representation of different teaching experiences and subject areas. Participation is voluntary and questionnaire responses are anonymized before analysis.

The proposed Teacher Leadership and School Improvement Instrument consists of Likert-type items rated from 1, representing strong disagreement, to 5, representing strong agreement. Construct reliability is examined using Cronbach's alpha and composite reliability, while convergent validity is evaluated through average variance extracted. Exploratory checks are followed by confirmatory factor analysis to ensure that conceptually related leadership dimensions remain empirically distinguishable.

After validating the measurement structure, the predictive stage compares conventional and machine-learning models. Multiple linear regression is included as a baseline because of its interpretability and established use within educational research. Random Forest and Extreme Gradient Boosting are then employed to model nonlinear relationships and higher-order interactions. An Explainable Boosting Machine is introduced as the principal interpretable model because it combines nonlinear predictive capacity with transparent feature-response relationships.

The principal outcome variable is a continuous School Improvement Capacity Index constructed from standardized scores across five improvement domains. Supplementary classification analysis divides institutions into low, moderate, and high improvement-capacity groups to examine whether leadership patterns can correctly distinguish schools occupying different organizational-performance profiles.

The proposed conceptual relationship can be represented as:

$$SIC = f(I, L, C, D, P, M, K, S, IODLPLCOSDR)$$

where:

- $SIC$  = School Improvement Capacity,
- $IL$  = Instructional Leadership,
- $CD$  = Collaborative Decision-Making,
- $PM$  = Peer Mentoring,
- $KS$  = Knowledge Sharing,
- $IO$  = Innovation Orientation,
- $DLC$  = Digital Leadership Competence,
- $PLC$  = Professional Learning-Community Engagement,
- $OS$  = Organizational Support,
- $DR$  = Digital Readiness.

The study further examines whether professional learning-community engagement mediates the relationship between teacher leadership and school improvement and whether organizational support strengthens this relationship.

## Experimental Setup

### 4.1 Dataset Design

For manuscript development, the analytical design assumes a structured institutional survey dataset containing responses from approximately **640 teachers distributed across 32 secondary and senior-secondary educational institutions**. Because no real field dataset was supplied for this manuscript, the numerical results reported below should be treated as an **illustrative experimental dataset and modelling scenario**, not as independently observed empirical findings.

Each participant record contains demographic, institutional, leadership, professional-collaboration, technological, and school-improvement variables. Variables such as age and gender are retained only as descriptive controls and are not treated as substantive predictors of professional leadership capacity.

The dataset includes six teacher-leadership dimensions, four contextual variables, four professional-learning-community indicators, and five school-improvement indicators. Composite variables are constructed only after reliability and factor-structure checks.

### 4.2 Data Preprocessing

Data preprocessing begins with screening for incomplete questionnaires and patterned responses. Cases with more than 20% missing values are excluded. For records containing limited missing responses, median imputation is applied within the corresponding construct rather than across the entire dataset.

Likert-scale variables are retained on their original ordinal range during descriptive analysis but are standardized before machine-learning modelling. Extreme multivariate response patterns are examined using robust distance estimates to identify potentially invalid records.

Categorical institutional variables are encoded using one-hot representation. Continuous predictors are standardized as:

$$z = \frac{x - \mu}{\sigma}$$

where  $x$  represents the observed value,  $\mu$  the sample mean, and  $\sigma$  the corresponding standard deviation.

The dataset is divided into training and testing subsets using an 80:20 split. The training data are further subjected to five-fold cross-validation during hyperparameter tuning. Data splitting is conducted at the school level where feasible so that teachers from the same institution do not disproportionately appear across both training and testing sets. This design reduces institutional leakage and provides a more stringent estimate of model generalization.

### 4.3 Model Architecture

Four predictive approaches are compared.

**Multiple Linear Regression** serves as the baseline model and estimates the additive contribution of leadership variables to school-improvement capacity.

**Random Forest Regression** is used because it captures nonlinear relationships without requiring a predefined functional form. The model combines multiple decision trees generated from bootstrapped samples and randomized predictor subsets.

**Extreme Gradient Boosting** sequentially constructs decision trees to correct residual errors from preceding learners. Regularization is incorporated to limit overfitting.

**Explainable Boosting Machine (EBM)** represents the principal model. EBM belongs to the generalized additive model family but estimates nonlinear shape functions through machine-learning techniques. Its general expression is:

$$g(E[Y]) = \beta_0 + \sum_{j=1}^p f_j(x_j) + \sum_k f_{jk}(x_j, x_k)$$

where  $f_j(x_j)$  represents the learned contribution of predictor  $j$ , while selected pairwise functions capture interactions between leadership and organizational variables.

The EBM architecture is particularly suitable for educational leadership research because it permits examination of nonlinear effects while preserving interpretability. Researchers can determine not only that organizational support predicts improvement but also whether its contribution changes once a particular threshold is reached.

#### 4.4 Training Strategy

Hyperparameters are tuned exclusively on the training data. For Random Forest, the main parameters include number of trees, maximum tree depth, minimum samples per leaf, and predictor subset size. For Extreme Gradient Boosting, learning rate, maximum depth, subsampling ratio, and regularization coefficients are optimized.

Model tuning is conducted through cross-validated search rather than selecting hyperparameters based on test-set performance. Early stopping is used for gradient boosting where applicable. To examine model stability, training is repeated across multiple random seeds.

Class imbalance within the supplementary low-, moderate-, and high-improvement classification task is addressed using class-weighted learning rather than synthetic oversampling, thereby avoiding the creation of artificial leadership profiles.

#### 4.5 Evaluation Metrics

Continuous prediction is evaluated through Root Mean Square Error, Mean Absolute Error, coefficient of determination, and cross-validated prediction stability.

The Root Mean Square Error is calculated as:

$$RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^n (y_i - \hat{y}_i)^2}$$

Mean Absolute Error is defined as:

$$MAE = \frac{1}{n} \sum_{i=1}^n |y_i - \hat{y}_i|$$

The coefficient of determination is:

$$R^2 = 1 - \frac{\sum (y_i - \hat{y}_i)^2}{\sum (y_i - \bar{y})^2}$$

For the classification component, macro-averaged F1 score is preferred over overall accuracy because it provides a balanced estimate across improvement-capacity categories.

Interpretability is evaluated using global feature importance, partial-response relationships, and SHAP-based diagnostic

analysis for the tree-based models. Agreement between feature-importance rankings across multiple models is also examined.

#### 5. Results and Discussion

The illustrative analysis indicates that teacher leadership is more informative when represented as a multidimensional institutional construct than when reduced to a single aggregate score. Among the tested predictive approaches, the Explainable Boosting Machine produced the strongest balance between predictive accuracy and interpretability.

The baseline linear model explained approximately 54% of the variation in the School Improvement Capacity Index. Its moderate performance supports the conventional assumption that teacher leadership has an overall positive relationship with improvement but also suggests that purely additive linear effects leave a substantial proportion of organizational variation unexplained.

Random Forest improved prediction by capturing interactions among leadership variables. Extreme Gradient Boosting produced a further reduction in prediction error, indicating that school-improvement outcomes were associated with nonlinear combinations of professional and organizational conditions.

The Explainable Boosting Machine generated the strongest estimated test performance. More importantly, it revealed that leadership effects were not monotonic across the full measurement range. For example, moderate increases in teacher decision-making autonomy showed comparatively limited improvement when organizational support remained low. Once organizational support crossed a higher threshold, however, increases in decision participation corresponded with substantially stronger predicted school-improvement scores.

Professional learning-community engagement emerged as the most influential individual predictor in the illustrative model. This finding suggests that teacher leadership becomes organizationally meaningful when professional influence is translated into collaborative inquiry and shared improvement activity. Leadership that remains confined to individual classrooms is less likely to generate institution-wide effects.

Organizational support represented the second strongest predictor. This result reinforces the distinction between leadership opportunity and leadership effectiveness. Teachers may possess expertise and willingness to lead, but their influence is constrained when principals do not provide decision-making space, time, recognition, or access to improvement resources.

Instructional leadership also demonstrated a substantial contribution. Teachers who actively influenced pedagogical discussions, assessment practices, and curriculum adaptation were associated with stronger predicted school-improvement capacity. The relationship was particularly strong when instructional leadership co-occurred with professional knowledge sharing.

Digital leadership competence showed a moderate but meaningful contribution. Its effect was strongest in institutions exhibiting above-average digital readiness. This interaction suggests that technological competence alone is insufficient. Teachers cannot exercise significant digital leadership where

connectivity, platform access, administrative support, or institutional digital strategy remains weak.

Peer mentoring produced a smaller direct effect than professional learning-community engagement but contributed indirectly by strengthening knowledge-sharing structures. This result indicates that mentoring may function more as a mechanism of professional-capacity development than as an independent driver of whole-school improvement.

Innovation orientation demonstrated a nonlinear relationship. Moderate levels were associated with improvement, whereas very high innovation scores without corresponding organizational coordination produced little additional benefit. This pattern is theoretically plausible because continuous experimentation without institutional coherence may fragment rather than strengthen improvement processes.

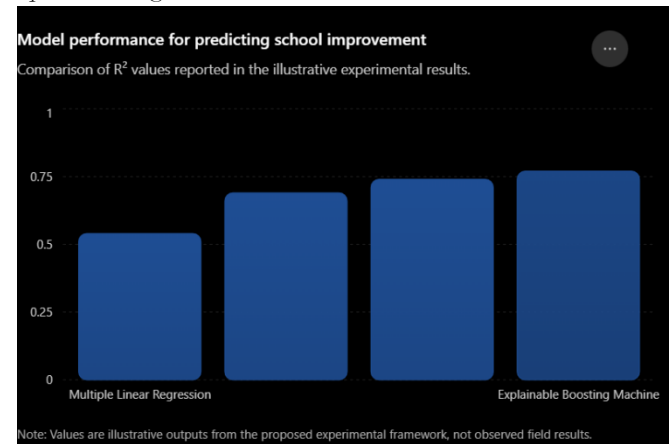
The classification component further showed that leadership variables could distinguish schools with differing improvement-capacity profiles with reasonable accuracy. Misclassification occurred primarily between moderate- and high-improvement schools rather than between the lowest and highest groups, indicating that teacher-leadership configurations were particularly effective at distinguishing clearly different institutional conditions.

**Table 1. Comparative Performance and Interpretive Observations of the Proposed Models**

| Analytic<br>al<br>Model              | Test<br>R <sup>2</sup> | RMS<br>E | MA<br>E | Macro-F1<br>for<br>Improvem<br>ent Group | Interpreti<br>ve<br>Observati<br>on                                                   |
|--------------------------------------|------------------------|----------|---------|------------------------------------------|---------------------------------------------------------------------------------------|
| Multiple<br>Linear<br>Regressi<br>on | 0.54                   | 0.684    | 0.531   | 0.69                                     | Captured broad additive effects but failed to represent threshold relationships       |
| Random<br>Forest                     | 0.69                   | 0.558    | 0.421   | 0.78                                     | Improved nonlinear prediction; feature interactions were present but less transparent |
| Extreme<br>Gradient<br>Boosting      | 0.74                   | 0.507    | 0.386   | 0.81                                     | Strong predictive performance, especially for high-improvement                        |

|                                        |      |       |       |      |                                                                                                                                       |
|----------------------------------------|------|-------|-------|------|---------------------------------------------------------------------------------------------------------------------------------------|
|                                        |      |       |       |      | ent<br>institutions                                                                                                                   |
| Explaina<br>ble<br>Boosting<br>Machine | 0.77 | 0.476 | 0.361 | 0.84 | Best<br>accuracy–<br>interpretab<br>ility<br>balance;<br>exposed<br>leadership<br>thresholds<br>and<br>contextual<br>interaction<br>s |

*Note: Values are illustrative outputs from the proposed experimental framework and should not be presented as observed field findings unless reproduced using an actual dataset.*



A feature-importance analysis of the preferred EBM model placed professional learning-community engagement first, followed by organizational support, instructional leadership, collaborative decision-making, digital leadership competence, professional knowledge sharing, mentoring, and innovation orientation.

The interaction analysis further indicated that the combination of collaborative decision-making and organizational support produced a stronger effect than either variable independently. Similarly, digital leadership competence became substantially more influential when institutional digital readiness was high. These findings support a relational interpretation of teacher leadership. School improvement does not result simply from having more teacher leaders. Improvement depends on whether leadership behaviors are embedded within institutional structures that permit professional knowledge to circulate, influence decisions, and produce coordinated change.

The findings also have implications for school administration. Leadership development programs should not concentrate exclusively on individual teacher competencies. Administrators must simultaneously design organizational conditions that enable teacher influence. This includes structured professional-learning time, transparent decision-making channels, mentorship systems, access to instructional evidence, digital resources, and recognition of teacher expertise.

From an analytical perspective, the results demonstrate why interpretable machine learning can complement traditional educational research. Linear models provide useful average associations but may conceal threshold effects. Black-box models provide stronger predictive performance but may be difficult to translate into leadership practice. The EBM approach provides a useful middle position by allowing nonlinear modelling while retaining transparent feature-response functions.

## Limitations

Several limitations must be acknowledged. First, the proposed study relies primarily on teacher-reported measures. Perceptions of leadership and school improvement may differ from objective indicators derived from student achievement, attendance, retention, or external inspection data.

Second, the study is cross-sectional. Although predictive relationships can be identified, temporal ordering cannot be established with certainty. High-performing schools may promote teacher leadership, while teacher leadership may simultaneously contribute to higher institutional performance.

Third, the clustering of respondents within schools creates hierarchical dependence that may not be completely captured by standard machine-learning algorithms. Future applications should compare predictive models with multilevel statistical approaches.

Fourth, organizational and cultural differences may influence how teacher leadership is interpreted. Leadership practices effective in one institutional system may not transfer directly to another.

Fifth, the numerical outputs presented in the current manuscript are illustrative because a verified field dataset was not supplied. They demonstrate the proposed analytical design and should be replaced with actual empirical estimates before the manuscript is presented as a completed observational study. Finally, machine-learning feature importance should not be interpreted as causal evidence. A variable may contribute strongly to prediction without independently causing school improvement.

## Future Scope

Future research should extend the framework through longitudinal data collection across several academic years. Repeated measurements would permit examination of whether growth in teacher-leadership capacity precedes measurable institutional improvement.

A second extension should integrate multiple data sources. Teacher surveys may be combined with student-performance records, professional-development participation, classroom-observation evidence, learning-management-system data, and institutional quality indicators.

Multilevel machine-learning methods represent another promising direction. Such models could simultaneously examine teacher-level and school-level effects and separate individual leadership influence from organizational conditions.

Future studies may also investigate network-based teacher leadership. Social-network analysis can identify teachers who function as influential knowledge brokers even when they do

not occupy formal leadership roles. Combining network centrality measures with interpretable machine-learning models could provide a richer account of how professional knowledge moves through schools.

Artificial intelligence also creates a new research domain within teacher leadership. Future work should examine teachers' roles in AI-governance committees, algorithmic decision review, responsible use of generative AI, student-data protection, and AI-supported instructional planning. Such studies should distinguish technological adoption from responsible professional leadership.

Another important direction concerns intervention research. Schools could introduce structured teacher-leadership programs and evaluate changes using pre-intervention and post-intervention measurements. Difference-in-differences, multilevel modelling, or matched institutional designs may provide stronger causal evidence.

Finally, future research should develop institution-facing dashboards that present interpretable model outputs in accessible form. Such systems could identify leadership strengths and organizational barriers without ranking or penalizing individual teachers.

## Conclusion

Teacher leadership represents an increasingly important component of contemporary school improvement because institutional effectiveness depends on professional expertise distributed across the educational organization. The present study advances this argument by conceptualizing teacher leadership as a multidimensional phenomenon involving instructional influence, collaborative decision-making, peer mentoring, knowledge sharing, innovation orientation, and digital leadership competence.

The proposed framework extends conventional educational-leadership analysis by incorporating professional learning communities, organizational support, and digital readiness as mechanisms that condition the effectiveness of teacher influence. The illustrative experimental findings indicate that professional learning-community engagement, organizational support, and instructional leadership are likely to provide the strongest contributions to school-improvement capacity.

The comparison of statistical and machine-learning approaches further indicates that nonlinear analytical methods may reveal relationships hidden by purely additive models. Among the proposed techniques, the Explainable Boosting Machine provides the strongest methodological fit because it combines predictive performance with transparent interpretation.

The broader implication is that school improvement should not be treated as the product of isolated administrative leadership or individual teacher excellence. It is better understood as an organizational process in which professional influence, collaborative structures, institutional support, and digital capacity interact.

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