

Mapping Teacher Typologies in Indonesian Madrasahs Using Fuzzy C-Means: Competence Development, Loyalty, Discipline, and Motivation

Asep Abdullah^{*1}, Badrudin¹, Qiqi Yuliati Zaqiah¹, Dian¹

¹ Universitas Islam Negeri Sunan Gunung Djati Bandung, Indonesia

*Corresponding Author: 4bdullahasep@gmail.com

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ABSTRACT. Teacher development in madrasahs is often managed as if teachers form a single continuum of quality, even though competence development, organizational attachment, discipline, and motivation may combine in different ways. Existing typologies in teacher development commonly rely on hard partitions or focus on a narrower set of dimensions, leaving limited evidence on configuration-based, graded-membership typologies that integrate these four work-related constructs in Indonesian madrasah contexts. This study addresses that gap by mapping teacher typologies from the joint configuration of competence development (PKG), loyalty (LOY), work discipline (DIS), and work motivation (MOT) using a quantitative, person-centered approach. Survey data from 285 madrasah teachers were screened to reduce the influence of extreme outliers and standardized to Z-scores. Fuzzy C-Means clustering with Euclidean distance ($m = 2$) was estimated across candidate solutions ($k = 1-10$). A four-cluster solution was retained as the most defensible balance of parsimony and substantive interpretability under comparative model-selection indices and global adequacy evidence ($R^2 = 0.41699$; silhouette = 0.26000). The typology comprises two pole profiles (Overall High; Overall Low) and two trade-off profiles (Discipline–Motivation; High PKG–Low Discipline). The modest silhouette indicates meaningful overlap; therefore, use profiles as dominant tendencies and apply membership grades to identify core versus transitional cases. Practically, the map supports differentiated professional development in madrasahs by tailoring support packages to alignment problems across capability building, institutional attachment, disciplined enactment, and motivational conditions rather than relying on one-size-fits-all training.

Keywords: *Fuzzy C-Means clustering, teacher typologies, teacher professional development.*

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INTRODUCTION

Teacher development in Indonesian madrasahs is often organized through uniform programs, although teachers may display different combinations of competence development, institutional loyalty, work discipline, and work motivation under comparable institutional expectations (Daulay et al., 2024; Maqfirah et al., 2026; Quynh & Nguyen, 2026; Rofiq et al., 2025; Sitepu et al., 2025). Averages can conceal these within-population differences, making generic coaching, supervision, and incentives less responsive to teachers' actual development needs. Person-centered approaches are intended to describe such heterogeneity rather than reduce teacher functioning to one score (A. J. S. Morin et al., 2018; Spurk et al., 2020). Empirical studies have also identified distinct patterns of teacher stress, coping, and work engagement (Göncz, 2017; K. C.

Herman et al., 2018). In Islamic educational settings, loyalty and discipline are shaped not only by individual characteristics but also by institutional values and leadership practices (Afandi, 2025; Ahyani et al., 2024; Khofi et al., 2026; Sukarjono et al., 2026; Yuliana et al., 2025).

The four constructs may align or diverge because they represent different aspects of professional functioning. Competence development concerns teachers' capacities, loyalty their organizational attachment, discipline the consistency of professional routines, and motivation their willingness to sustain effort. Human capital theory supports the importance of capacity development (Becker, 1966), while motivation theory emphasizes quality of regulation and need satisfaction (Deci & Ryan, 2000). Continuous improvement also depends on routines that convert resources into practice (Deming, 1986). Accordingly, stronger competence development need not coincide with stronger loyalty, discipline, and motivation in every teacher. A multidimensional analysis is therefore more informative than an assumption that all four attributes increase together.

Previous person-centered studies have identified different teacher configurations in emotional labor, motivation, commitment, and teaching quality, demonstrating the value of analyzing patterns rather than isolated predictors (Burić et al., 2021; Hu et al., 2023; Meyer et al., 2019; Nirmala et al., 2025; Sholeh et al., 2024). Methodological guidance cautions that apparent profiles may depend on model choices and should not be interpreted as definitive classes without sufficient separation and replication (Daumiller et al., 2023; A. J. S. Morin et al., 2018; Spurk et al., 2020). Recent teacher-related applications have used fuzzy clustering to examine ambiguous multidimensional patterns (RAD et al., 2025; Waryanto et al., 2025), while research in Indonesian madrasahs has examined the organizational roles of leadership, work ethic, motivation, and discipline (Aceh et al., 2024; Adiyono et al., 2026). However, limited evidence integrates competence development, loyalty, work discipline, and motivation into one graded-membership map for madrasah teachers.

Fuzzy C-Means offers a way to address this gap because it allows individuals to resemble more than one profile instead of imposing wholly rigid boundaries. That property is pertinent when teachers can score relatively high on one construct and lower on another. The contribution sought here is not a causal estimate or a universal teacher taxonomy but an exploratory map of joint configurations that can inform differentiated professional-development decisions. The study asks which dominant patterns emerge across competence development (PKG), loyalty (LOY), discipline (DIS), and motivation (MOT), and what their relative overlap implies for interpreting teachers' support needs in madrasahs. This bounded novelty builds on existing person-centered research without assuming that a specific number of clusters is statistically optimal.

Using survey data from teachers at 14 public madrasahs in Tasikmalaya Regency, this study applies Fuzzy C-Means to standardized scores for the four constructs and evaluates the resulting profiles using model diagnostics and substantive interpretability. Its guiding argument is that teacher functioning may exhibit both aligned configurations and cross-construct trade-offs, with some teachers located near profile boundaries. These expectations are exploratory descriptions to be assessed against observed patterns, not confirmatory hypotheses about causal effects. The findings are discussed as conditional profile tendencies relevant to supervision and professional development, with attention to uncertainty and the limits of classification.

METHOD

Study Design and Setting

This study used a cross-sectional survey design with a quantitative, person-centered analytic goal: to map teacher typologies from the joint configuration of competence development (PKG), loyalty (LOY), work discipline (DIS), and work motivation (MOT). The analytic focus is configurational rather than causal, so the design prioritizes comparative pattern detection and interpretability in standardized score space.

The empirical setting comprised 14 public Madrasah Tsanawiyah Negeri (MTsN) in Tasikmalaya Regency, Indonesia. This setting was selected because the madrasahs had implemented relatively systematic and sustained teacher development initiatives and were reported to show meaningful improvement in teacher performance, making them an informative context for examining how competence development aligns or misaligns with loyalty, disciplined enactment, and motivation under Islamic educational management conditions.

Participants

A total of 286 teachers completed the survey across 14 public Madrasah Tsanawiyah Negeri (MTsN) in Tasikmalaya Regency, Indonesia. One case was excluded due to incomplete composite scores on at least one construct, yielding 285 usable cases for the fuzzy clustering analysis. School-level contributions varied substantially, ranging from 2 to 40 teachers per madrasah, with the largest contributions from MTsN 1 Sukarama, MTsN 6 Cikatomas, and MTsN 11 Tanjungjaya, and the smallest from MTsN 5 Cipatujah.

The gender distribution comprised 154 male teachers (53.85%) and 132 female teachers (46.15%). Most respondents held a bachelor's degree (S1; $n = 274$, 95.80%), while a smaller proportion held a master's degree (S2; $n = 12$, 4.20%). These characteristics provide a necessary basis for interpreting the typology and assessing external validity.

Survey Design and Measures

Data were collected using a structured questionnaire administered to teachers. Responses were recorded on a 5-point Likert scale ranging from Strongly Agree (5) to Strongly Disagree (1). The questionnaire contained 54 items administered via an online form. Items were mapped to the study constructs through an operational specification table linking variables, dimensions, indicators, and item numbers.

Each construct was measured with multi-item Likert-type scales and scored to yield one composite per construct prior to standardization. Composite scores were computed by aggregating item responses within each construct using the same direction of scoring across items. Internal consistency of the composite scales was checked prior to clustering using Cronbach's alpha. The resulting construct scores were then standardized and used as the sole inputs for fuzzy clustering.

Data Screening, Missingness, and Standardization

Prior to clustering, data were screened to support distance-based modeling and to reduce undue influence from atypical observations. Cases with incomplete composite scores on any of the four constructs were excluded listwise, yielding 285 usable cases for clustering.

To ensure comparability across constructs and to prevent scale range from dominating Euclidean distances, each construct was transformed into a Z-score (PKG_Z, LOY_Z, DIS_Z, MOT_Z). The standardized features were the sole inputs for clustering so that cluster structure reflected relative standing across the four dimensions rather than differences in raw scale. Standardized-score inspection indicated a small number of isolated observations but did not warrant additional case deletion beyond the listwise exclusion.

Why Fuzzy C-Means

Fuzzy C-Means (FCM) was selected because the substantive premise of the study is that teacher profiles may overlap: a teacher may resemble one profile on competence development while simultaneously resembling another profile on discipline or motivation. Hard-partition techniques (for example, k-means) force each teacher into exactly one cluster, which can misrepresent boundary cases as classification errors. In contrast, FCM assigns graded memberships across clusters, allowing typologies to be interpreted as dominant tendencies with transitional cases. This is particularly suitable for teacher development contexts where roles, constraints, and institutional expectations produce partial alignment among PKG, LOY, DIS, and MOT rather than a single continuum.

FCM is also practically advantageous for professional development design: membership grades can be used to separate core cases (high membership in a profile) from mixed cases (distributed membership), supporting staged or hybrid interventions rather than rigid assignment.

Fuzzy C-Means Procedure and Model Selection

Clustering was estimated using Euclidean distance with fuzziness parameter $m = 2$, a common setting that balances crispness and overlap. Candidate solutions were examined for $k = 1$ to $k = 10$ to avoid committing to a single assumed number of profiles. The retained solution was selected by triangulating global and local diagnostics, including R^2 , AIC, BIC, global silhouette, cluster sizes, within-cluster dispersion, cluster-specific silhouette scores, and substantive interpretability.

Because the global silhouette was modest, selection was not treated as a search for “perfect partitioning.” Instead, the decision rule emphasized whether adding or removing clusters improved separation meaningfully while preserving interpretable and actionable configurations. In reporting, the comparison logic should be made explicit by summarizing the candidate solution table (Table M3), including why adjacent solutions (for example, $k = 3$ or $k = 5$) were not retained based on selection indices, cluster stability, and interpretability.

Sample Size Considerations and Robustness

The sample size ($N = 285$) is adequate for exploratory clustering with four standardized features, but it does not justify treating the solution as a definitive taxonomy. Accordingly, the typology is interpreted as a context-specific map for Indonesian madrasah teachers in the observed setting. Robustness and generalizability require replication in independent madrasah samples and sensitivity analyses under alternative preprocessing and fuzziness specifications.

Software

All analyses were implemented in JASP using its fuzzy clustering workflow.

RESULT AND DISCUSSION

Result

The four measured constructs, namely competence development (PKG), loyalty (LOY), work discipline (DIS), and work motivation (MOT), did not move in a single aligned direction among madrasah teachers. The clustering output is therefore read as a map of dominant tendencies showing how these four dimensions combine into several configurations, including boundary regions where teachers legitimately sit between two tendencies. In this framing, the typology supports differentiated professional development and leadership support, rather than functioning as a rigid labeling scheme.

Global Adequacy of the Four-Cluster Typology Solution

The model was estimated on four Z-score features with fuzziness $m = 2$ after comparing candidate solutions from $k = 1$ to $k = 10$. The retained solution ($k = 4$) yields $R^2 = 0.41699$, indicating that the cluster structure accounts for a substantive share of variation in the feature space. The global silhouette of 0.26000 indicates only moderate separation; overlap and boundary cases are therefore expected and must be carried forward into practical interpretation.

Table 1. Model Summary: Fuzzy C-Means Clustering

Clusters	N	R^2	AIC	BIC	Silhouette
4	285	0.41699	348.38000	406.82000	0.26000

Cluster Quality Diagnostics: Size, Cohesion, and Separation

Cluster diagnostics show uneven profile sharpness. Cluster 1 is the most compact (lowest within sum of squares = 34.51100) and has the highest silhouette (0.32845). Cluster 4 is the weakest in distinctiveness (silhouette = 0.11167) and the most internally dispersed (highest within sum of squares = 142.80853), so it is best treated as a heterogeneous low region rather than a uniformly cohesive profile.

Table 2. Cluster Information

Cluster	1	2	3	4
Size	51	66	118	50
Explained proportion within-cluster heterogeneity	0.10908	0.16948	0.27005	0.45139
Within sum of squares	34.51100	53.61851	85.43737	142.80853

Silhouette score	0.32845	0.24395	0.29194	0.11167
Center PKG_Z	-0.55909	0.25128	0.43220	-0.19703
Center LOY_Z	-0.47772	-0.03608	0.60366	-0.33359
Center DIS_Z	0.33904	-0.46830	0.60996	-0.68072
Center MOT_Z	0.21011	-0.06561	0.50613	-0.54440

Typology definition and mean-pattern contrasts

Four typologies emerged as two pole profiles and two trade-off profiles. Configuration contrasts are described using mean Z-scores, while cluster centers serve as prototypes for interpreting graded membership.

Table 4. Cluster Means

	PKG_Z	LOY_Z	DIS_Z	MOT_Z
Cluster 1	-0.49825	-0.50976	0.41806	0.38282
Cluster 2	0.45305	0.09596	-0.42012	0.02318
Cluster 3	0.43814	0.61665	0.61119	0.50859
Cluster 4	-0.93648	-0.85902	-1.12873	-1.43211

Two pole profiles and two trade-off profiles are visible in the mean Z-score patterns (Table 4). One pole reflects a broadly aligned “overall high” configuration, whereas the other pole reflects a low-score region. Between these poles, two trade-off configurations capture misalignment between capability building and disciplined enactment, or between disciplined effort and organizational attachment.

Cluster 3 (Overall High) shows consistently positive mean Z-scores across competence development, loyalty, work discipline, and work motivation (Table 4). With the largest cluster size ($n = 118$) and an adequate silhouette score (0.29194), it is among the more defensible labels in the solution even under moderate global separation. In development terms, the leverage point is not basic upskilling but system contribution: teachers close to this prototype can be positioned as peer mentors, lesson-study facilitators, or PLC leaders, provided leaders manage workload and recognition to prevent overload and role fatigue.

Cluster 1 (Discipline–Motivation) combines above-average discipline and motivation with below-average competence development and loyalty (Table 4). This pattern is consistent with a conversion gap: routines and effort exist, yet they are not translating into competence growth and stronger organizational attachment. Statistically, Cluster 1 is the most compact and best separated group in the solution (silhouette 0.32845; within sum of squares 34.51100), supporting its use as a relatively sharp reference profile. Practically, this configuration points to structured coaching and observation-based feedback that links existing routines to targeted competence gains, alongside leadership actions that strengthen belonging and perceived organizational fairness.

Cluster 2 (High PKG–Low Discipline) shows above-average competence development with below-average work discipline and near-average motivation (Table 4). The dominant contrast is therefore misalignment between capability and enactment consistency rather than a general “high” profile. Its silhouette (0.24395) indicates only moderate separation, which aligns with the broader overlap in the global diagnostics and implies that boundary cases are expected. The most defensible response is implementation support rather than additional competence training: clear process standards, light but consistent monitoring of a small set of routines, process-oriented supervision, and work-design adjustments that reduce frictions that undermine enactment discipline.

Cluster 4 represents a low-score region with negative means across all four dimensions, especially work discipline and motivation (Table 4). However, it is also the least distinct and most internally dispersed cluster (silhouette 0.11167; explained within-cluster heterogeneity 0.45139; within sum of squares 142.80853), which supports interpreting it as a heterogeneous low region rather than a single cohesive profile. Accordingly, the practical response is triage rather than a one-package intervention: program placement should rely on membership grades and additional diagnostic information (for example workload, leadership support, or work well-being) to separate high-risk core cases from boundary cases that are better served by dimension-specific remediation and staged support.

Visual Evidence: Mean Profiles, Proximity, and Overlap

Visual checks were used to complement the numeric diagnostics and to locate where overlap concentrates in the score space. The mean-profile plot provides a compact summary of configuration contrasts across PKG_Z, LOY_Z, DIS_Z, and MOT_Z, while the t-SNE plot offers a proximity-oriented view of local neighborhoods. The cluster matrix plot supports pairwise inspection of feature projections, and the density plots summarize within-cluster score distributions.

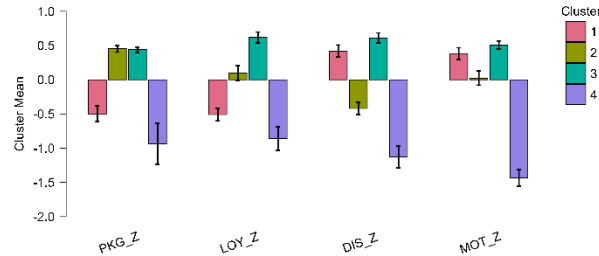


Figure 1. Cluster Mean Plot (All Features)

The mean-profile plot summarizes standardized mean patterns across PKG_Z, LOY_Z, DIS_Z, and MOT_Z for the four clusters, making pole-versus-trade-off contrasts easier to inspect.

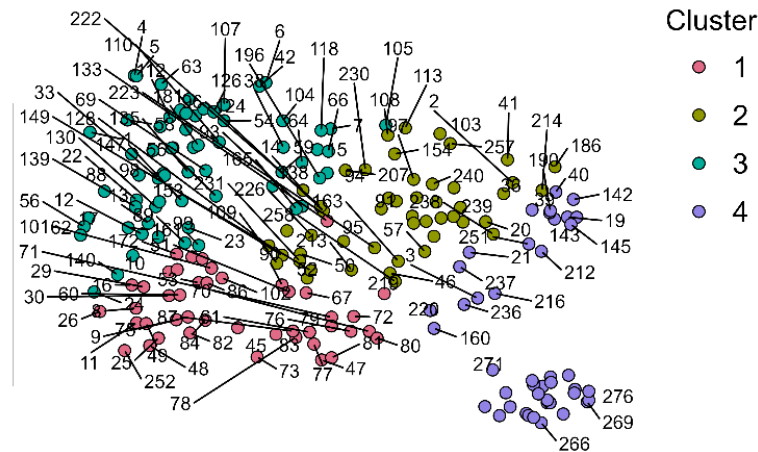


Figure 2. t-SNE Cluster Plot

The t-SNE map provides a proximity-oriented view of local neighborhoods to indicate where overlap is most likely, and it is interpreted descriptively rather than as a metric proof of separation.

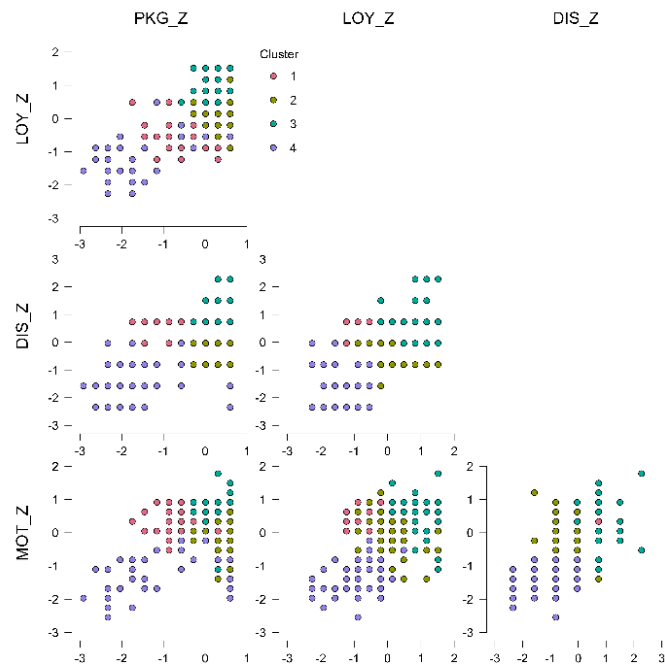


Figure 3. Cluster Matrix Plot The pairwise projection matrix complements the t-SNE view by showing how separation and overlap appear across different feature pairs.

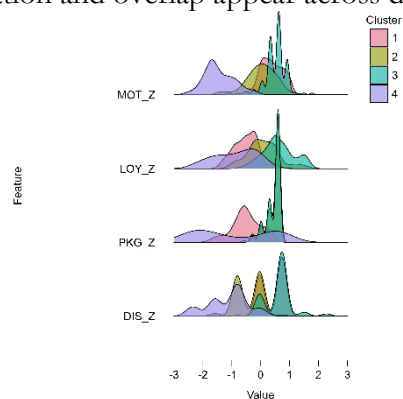


Figure 4. Cluster Density Plots (All Features)

Density plots display within-cluster score distributions for each feature, clarifying whether overlap is driven more by mean similarity or by dispersion.

Mapping typologies to differentiated professional development foci

To ensure practical alignment, each typology is mapped to a distinct support focus. This mapping provides a results-level summary; the policy rationale and mechanisms are elaborated in the Discussion.

Table 5. Typology-to-Development Mapping

Typology (Cluster)	Short pattern	Se pa rat ion qu alit y	Most defensible development focus
Overall High (3)	All dimensions positive	Mo der ate (0. 29 19 4)	System-leverage roles, peer coaching, PLC leadership

Discipline–Motivation (1)	High DIS and MOT; low PKG and LOY	Strongest (0.32845)	Targeted competence coaching + attachment-building supports
High PKG–Low Discipline (2)	High PKG; low DIS; MOT near average	Moderate (0.24395)	Implementation supports, routines, process supervision, standards
Low region, high dispersion (4)	Low across features, especially DIS and MOT	Weakest (0.11167)	Membership-grade triage + additional diagnosis; layered support

Overlap Patterns and Practical Consequences of Profile Distinction

Distance-based indices indicate intersecting cluster boundaries. The minimum separation (0.28823), small relative to the maximum diameter (4.47574), confirms that clusters are close in parts of the score space, making practical distinction most fragile between the two trade-off profiles (Clusters 1 and 2). Even so, these two profiles retain a clear directional contrast on two key dimensions: PKG_Z and DIS_Z have opposite signs (Cluster 1: PKG negative, DIS positive; Cluster 2: PKG positive, DIS negative). Operationally, distinction should therefore rely on this PKG–DIS contrast and on graded membership, rather than on binary labels.

Cluster 4's weak cohesion also means that an "Overall Low" label must be used cautiously. Operationally, Cluster 4 is best treated as a signal for further screening rather than as a single intervention target, because high internal dispersion suggests that low scores can stem from different underlying causes.

Membership Sharpness and Operational Rules for Practice

Because the approach is fuzzy, quality is not only about geometric separation (silhouette and inter-cluster distances) but also about how sharp membership is within profiles. The entropy index (1.31711) indicates high membership uncertainty. For $k = 4$, the theoretical maximum entropy is $\ln(4) = 1.38629$, so 1.31711 lies close to the maximum and is consistent with many mixed-membership cases rather than clearly core members.

Table 6. Membership Uncertainty and Distance-Based Geometry

Metric	Value	Interpretive implication
Entropy	1.31711	High uncertainty; many mixed-membership cases
Maximum diameter	4.47574	Wide overall spread in score space
Minimum separation	0.28823	Clusters are close in parts of the space
Dunn indeks	0.06440	Low clean separation; overlap is substantial
Pearson's γ	0.45343	Structured grouping exists, but not sharp
Calinski–Harabasz indeks	134.99619	Supports structure, without guaranteeing crisp boundaries

To make the typology operational for professional development, cluster labels should not be used as binary assignments. Instead, use the maximum membership grade ($u_{\max}$) to separate core from transitional cases.

Table 7. Operational Membership-Grade Rules for Differentiated Support

Membership category	Rule ($u_{\max}$)	Practical meaning
Core member	≥ 0.70	Primary target for profile-specific program; direct intervention is defensible
Near-core	0.55–0.69	Main candidates with minor adjustments; core program plus tailoring
Transitional	0.40–0.54	Boundary cases; require additional diagnosis and staged/hybrid support
Diffuse/mixed	< 0.40	Membership is dispersed; avoid single labels; prioritize contextual assessment

In reporting, the distribution of $u_{\max}$ by cluster can be summarized (for example, the proportion with $u_{\max} \geq 0.70$) to indicate how many actionable core members exist for profile-based interventions. In school practice, these rules support combining typology segmentation with individual needs assessment so that decisions do not depend on inherently overlapping cluster boundaries.

Discussion

The four-profile map reinforces a configuration view of teacher functioning: competence development, organizational attachment, disciplined enactment, and motivational conditions can align, partially decouple, or trade off rather than collapse into a single “teacher quality” continuum (A. Morin et al., 2018; Spurk et al., 2020). The two pole patterns suggest that some teachers occupy broadly aligned regimes, whereas the two trade-off patterns indicate governance tension points where capability does not automatically translate into consistent enactment, and disciplined effort does not automatically translate into competence growth or stronger organizational attachment. This configuration logic is consistent with person-centred evidence that teachers cluster into qualitatively different patterns of functioning, engagement, and work-related experiences, with implications that average trends typically conceal (Collie et al., 2020; K. Herman et al., 2018; Perera et al., 2021). Numerically, the four-cluster solution explains a substantive share of variation ($R^2 = 0.41699$) but remains only moderately separated (global silhouette = 0.26000), and the small minimum separation (0.28823) relative to the maximum diameter (4.47574) confirms substantial overlap in parts of the score space.

The practical value of the typology depends on whether it can be converted into differentiated professional development pathways without treating profiles as rigid labels. Given the modest global silhouette and the high membership uncertainty (entropy close to $\ln(4)$), the defensible operating rule is to begin with membership grades and to distinguish core from transitional cases before assigning programs (A. Morin et al., 2016; Spurk et al., 2020). Teachers close to the Overall High prototype can be positioned as system levers through peer mentoring, lesson study facilitation, or PLC leadership, a strategy aligned with quality-improvement logic that emphasizes internal capability diffusion and routine strengthening rather than repeated generic training (Deming, 1986). In contrast, the Discipline–Motivation pattern points to a conversion gap: routines and effort exist, but the learning pathway is not producing sustained competence development or organizational attachment. Here, structured coaching and observation-based feedback are more defensible than workshops, paired with leadership actions that strengthen belonging and perceived fairness, which are consistently linked to how demands and resources translate into work-related functioning (Collie et al., 2020; Meyer et al., 2019).

The High PKG–Low Discipline pattern requires a different leadership diagnosis. Additional competence training is unlikely to be the binding constraint when competence development is already above average. Instead, the most plausible levers are implementation supports: clear process standards, light but consistent monitoring of a small set of instructional routines, and work-design adjustments that reduce frictions undermining disciplined enactment. This is compatible with evidence that teacher profiles can differ in how capability and motivation translate into practice and quality over time, making enactment consistency a distinct target rather than a by-product of skill acquisition (Thommen et al., 2021; Wal et al., 2014). In Islamic educational management contexts, disciplined enactment and loyalty are also shaped by institutional culture and leadership practices, so strengthening routines and attachment should be treated as organizational work, not as an individual moral deficit (Afandi, 2025; Khofi et al., 2026; Rasyidin et al., 2025).

At the policy and leadership level, the typology supports a portfolio approach to teacher development rather than uniform program allocation. A profile-informed portfolio allows resources to be directed to the dominant configuration problem: targeted competence coaching when capability is the bottleneck, implementation-and-routine strengthening when enactment is the bottleneck, and attachment-building mechanisms when organizational commitment is the bottleneck (Collie et al., 2021; Meyer et al., 2019). Leadership typology research further suggests that leadership practices can shape efficacy and commitment configurations through person-centred pathways, which strengthens the logic of using typologies as a decision aid for supervision and professional learning design rather than as a static classification (Ali et al., 2026; Bellibaş et al., 2022; Hariyani et al., 2025; Siswadi et al., 2026). The membership-grade rule also improves fairness and feasibility by reducing rigid labeling and enabling staged supports for mixed-membership cases,

an issue repeatedly emphasized in guidance on person-centred solutions and their comparability (Daumiller et al., 2023; A. Morin et al., 2016).

The weak cohesion of Cluster 4 deserves a critical reading. Statistically, Cluster 4 shows the weakest silhouette (0.11167) and the largest internal dispersion (within sum of squares = 142.80853; explained within-cluster heterogeneity = 0.45139), suggesting that the “low” region aggregates multiple causal stories rather than representing a single coherent profile. Substantively, low scores across PKG, LOY, DIS, and MOT can arise from different combinations of workload strain, weak attachment, fragile routines, or broader well-being constraints, a pattern consistent with multilevel evidence that workplace demands and resources form distinct regimes that shape teacher functioning (Collie et al., 2020; Collie & Mansfield, 2022). Methodologically, this is also a known risk in person-centred work: small separations can be over-interpreted, and clusters can appear as residual bins when boundary uncertainty is high (Daumiller et al., 2023; Spurk et al., 2020). This interpretation is consistent with the high membership uncertainty observed here (entropy = 1.31711, close to the maximum $\ln(4) = 1.38629$), which implies many mixed-membership cases rather than sharply core cases. In practice, this means that a one-package intervention for Cluster 4 is unlikely to be efficient; triage is more defensible, using membership grades to identify high-risk core cases for short-cycle intensive support and using dimension-specific remediation for boundary cases while monitoring membership shifts.

Compared with typology studies in other educational contexts, the pole-plus-trade-off structure is not unusual; it mirrors the broader finding that teacher engagement, motivation, commitment, and well-being often form mixed configurations with distinct implications for practice and outcomes (Burić et al., 2021; Meyer et al., 2019; Perera et al., 2021). The added value here is the explicit fuzzy logic stance: graded membership treats overlap as an empirical feature and enables flexible decision rules for transitional cases, echoing recent uses of fuzzy clustering for teacher-focused segmentation and evaluation under ambiguity (RAD et al., 2025; Waryanto et al., 2025). Under moderate separation, that flexibility is not optional; it is the condition for using typologies responsibly. Related work on profile change and transition dynamics further suggests that teacher configurations can shift over time, which strengthens the case for longitudinal follow-up and context-sensitive replication (Ilie et al., 2024; Miller et al., 2025; Wang et al., 2025).

CONCLUSION

The four-profile map indicates that competence development (PKG), loyalty (LOY), work discipline (DIS), and work motivation (MOT) do not form a single continuum in madrasah teachers. Two pole profiles (Overall High; Overall Low) coexist with two trade-off profiles (Discipline–Motivation; High PKG–Low Discipline), and the modest global separation (silhouette = 0.26000) implies that overlap is a substantive feature rather than a technical nuisance. Consequently, typologies should be treated as dominant tendencies supported by graded membership, not as rigid categories.

Academically, these findings extend prior person-centered teacher research by offering an exploratory graded-membership description of how competence development, loyalty, discipline, and motivation combine in madrasahs; external validation is needed before treating these four profiles as a generalizable taxonomy. For educational leaders, the practical value of the typology lies in converting broad, generic professional development into differentiated pathways. A defensible operating rule is to use the maximum membership grade ($u_{\max}$) to separate core cases from transitional cases before assigning support. Overall High teachers can be positioned as system leverage through peer coaching, lesson study facilitation, or mentoring roles, supported by workload management and recognition to prevent overload. Discipline–Motivation teachers benefit most from structured pedagogical coaching that converts strong routines and energy into targeted competence growth and stronger organizational attachment, complemented by fair task allocation and relational leadership practices. High PKG–Low Discipline teachers require implementation supports rather than additional competency training: clear process standards, light

but consistent monitoring, accountability routines, and work-design adjustments that reduce implementation frictions. The low region with weak cohesion should not receive a one-package intervention; it is best approached through triage using membership grades, short-cycle intensive support for high-risk core cases, and dimension-specific remediation for boundary cases.

Policy-wise, the typology supports a portfolio approach to teacher development in madrasahs by aligning program types with dominant configuration problems rather than distributing uniform training budgets. The main limitations remain the single-sample cross-sectional design, moderate separation that weakens categorical boundaries, and the heterogeneity of the low region (Cluster 4), which likely reflects multiple underlying causes and partial overlap with trade-off profiles. Future work should replicate the configuration across independent madrasah samples, integrate school-level conditions and leadership variables, and use longitudinal designs to test profile stability and transitions, thereby strengthening generalizability and decision usefulness.

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