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Article

Quantitative Validation of a Teacher Performance Measurement Model in Mathematics: Implications for Instructional Quality

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Abstract: This study aimed to develop a competency-based performance evaluation model for mathematics teachers at the junior secondary level. Recognizing the crucial role of teacher quality in student achievement, the study focused on measurable aspects of performance, including content mastery, instructional management, and professional commitment. A quantitative approach was employed using a research and development (R&D) framework, supported by a quasi-experimental design with pretest-posttest control groups. Data were collected via structured questionnaires, classroom observations, interviews, and expert validations through focus group discussions. Statistical analyses included descriptive statistics, ANOVA, t-tests, and confirmatory factor analysis using SPSS and LISREL. The results indicated that the developed model effectively differentiated teacher performance across various school categories, with 45% categorized as good, 53% adequate, and 2% poor. Student achievement was positively correlated, with 82% achieving the minimum competency threshold. The factor analysis confirmed a valid measurement model: F1 = 0.505ZX1 + 0.475ZX2 + 0.308ZX3, explaining 57.92% of the variance in teacher performance. The findings suggest that teacher evaluation must integrate multidimensional competencies and contextual factors to be accurate and actionable. This study contributes a validated, data-driven evaluation framework aligned with national standards and global educational expectations, offering practical implications for policy, supervision, and teacher development.

Keywords: Competency-based evaluation, Educational measurement, Instructional quality, Mathematics teacher performance, Teacher assessment model.

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1. Introduction

Improving the quality of education is highly dependent on the performance of educators, especially teachers, as the spearhead in the learning process. In this context, evaluating teacher performance is a strategic step to ensure that the educational process runs effectively and produces optimal learning outcomes [1][2][3]. This evaluation is an important instrument to measure the effectiveness of learning implementation and the pedagogical quality of teachers [4][5][6]. In the field of mathematics education, the importance of the role of teachers is very prominent, considering that this subject requires not only a deep conceptual understanding but also adequate pedagogical skills to convey abstract concepts systematically and meaningfully to students [7][8][9].

The literature shows that various challenges are constantly faced in improving the quality of performance of mathematics teachers, both in terms of material competence and mastery of innovative teaching methods [10][11][12]. Empirically, the results of observations show that the implementation of instruction by mathematics teachers is still not optimal

[13][14][15]. Performance scores in learning competencies show unsatisfactory numbers, indicating that the learning process has not been implemented comprehensively and per the set curriculum design [16]. These problems include a lack of skills in organizing instructional activities, incompetence in utilizing diverse learning approaches, weaknesses in classroom management, and a lack of optimal use of visual aids in fostering students' creativity, especially in the context of problem-solving [17][18][19].

Along with increasing public expectations of teacher professionalism, there is an urgent need to design a more comprehensive and reliable performance evaluation system. In Indonesia, teachers have a strategic role as learning agents, as affirmed in Government Regulation Number 19 of 2005 concerning the National Education Standards Agency. This regulation underlines that teacher at the primary, secondary, and early childhood education levels must have professional, pedagogical, social, and personality competencies [20][21][22]. However, there is still a gap between the competency standards set and real implementation in the field [23][24]. Therefore, there is an urgency to transform the teacher performance assessment system, especially for mathematics educators, to better reflect the complex dimensions of a teacher's duties.

The teacher performance evaluation model that has been applied is often still general and does not specifically accommodate the complexity of the role of mathematics teachers. The limited measurement tool that can systematically combine subject competence, pedagogical ability, and teacher professionalism is one of the main weaknesses of the existing evaluation system [25][26]. This shows the need to develop a competency-based performance evaluation methodology that not only ensures accountability but also encourages continuous improvement of teacher professionalism [27][28]. A measurable, systematic, and data-based evaluation model is needed so that the results of the evaluation can be used as a basis for teacher professional development planning in a targeted manner [29][30].

Several studies suggest a performance appraisal approach that includes a combination of qualitative and quantitative methods to get a comprehensive picture of teacher performance [31][32]. Qualitative methods can be in the form of classroom observations, portfolio assessments, and in-depth interviews, while quantitative methods include the use of explicit assessment rubrics and measurements based on numerical indicators [33][34][35]. The assessment indicators used in this model must reflect the essential competencies needed by a mathematics teacher, such as the ability to design learning, implement teaching strategies, and reflect or evaluate student learning outcomes [36][37]. In addition, the instruments used must go through a rigorous validation process through targeted group discussions involving experts in the field of education, so that the instruments have high validity and reliability [38][39].

Findings in various studies also support the importance of developing this evaluation model. For example, Tafqihan and Suryanto [40], Herawaty [41], Kartini and Kristiawan [42], and Marni et al. [43] emphasized that the performance of mathematics teachers is greatly influenced by several main variables, namely mastery of teaching materials, ability to manage learning, and commitment to professional duties as educators. This is strengthened by the findings of Domu [44] which states that these three variables are significant predictors in determining the performance of mathematics teachers in the classroom. Therefore, the performance evaluation model developed needs to be specifically designed to accommodate these three variables as key components.

However, an in-depth study of the form or model of the performance equation of mathematics teachers based on these three main variables is still limited. The available literature has not explored much about how the relationships between these variables can be modeled quantitatively in a complete performance evaluation framework that can be implemented practically in the field [45][46]. In addition, the limitations in the integration of multidimensional approaches between theoretical and practical aspects in performance evaluation are gaps that have not been addressed much in previous studies [47][48]. Therefore, further studies to build relevant and valid evaluation models are very crucial to support an education system that is more adaptive and responsive to the needs of teachers [49][50][51].

This study aims to formulate a model for evaluating the performance of mathematics teachers based on mastery of teaching materials, learning management skills, and professional commitment as a mathematics educator. The novelty of this study lies in the preparation of a mathematical model that describes the relationship between the three variables in determining teacher performance. By formulating this model, a more objective, valid, and applicable evaluation instrument can be obtained in the context of coaching and developing mathematics teachers in Indonesia. In addition, this study also contributes to strengthening the theoretical

and empirical basis regarding teacher performance evaluation through an integrative approach between quantitative data and conceptual analysis.

2. Proposed Method

This study uses a Research and Development (R&D) approach with a quantitative foundation as the main framework in designing, developing, and evaluating competency-based mathematics teacher performance evaluation models. The R&D approach was chosen because it allows researchers to produce educational products that are both applicable and empirically tested. The applied development model is designed to respond to practical needs in the field and reinforce the conceptual and empirical validity aspects of the developed evaluation instruments.

The experimental design used in this study is a pretest-posttest with control group design, where the experimental and control groups are measured both before and after the treatment is applied. This design provides a strong comparative picture in assessing the effectiveness of the developed evaluation model, especially in improving the performance of mathematics teachers in the context of learning.

The population in this study is all mathematics teachers at the junior high school (SMP) level who have been certified as educators. Sampling was carried out by a random sampling technique, considering the category of schools based on their status, namely National Standard Schools (SSN), International Standard Schools (RSBI), and National Standard School Pioneers (RSSN). The selection of samples that considers the diversity of school status is intended to improve the generalization of research findings, as well as ensure that the evaluation model developed can be applied in a variety of formal education contexts at the junior secondary level.

For data collection, various instruments are used to support the principle of data triangulation. The main instrument is a teacher performance assessment questionnaire, which is prepared based on the dimensions of professional competence, pedagogy, and commitment to the profession. In addition to the questionnaire, data were also collected through focused observation sheets used during the learning process, as well as in-depth interview guidelines designed to explore teachers' perspectives on the implementation and development of their professionalism. The initial validation of the instrument was carried out through the distribution of assessment sheets to validators consisting of mathematics education experts and learning practitioners.

One important component of the validation process is the implementation of Focus Group Discussions (FGD) involving experts and practitioners in mathematics education. This group discussion aims to obtain substantive input on the substance and structure of the developed model and ensure that the evaluation instrument prepared is relevant and clear in its application. FGD is carried out systematically at the initial validation stage before the instrument is tested on a limited basis.

Data obtained from questionnaires, observations, and interviews were analyzed using descriptive statistical techniques to obtain an overview of teacher performance, as well as inferential analysis in the form of t-tests and ANOVA to test the differences in performance between the experimental and control groups. Quantitative data processing is carried out with SPSS software version 16.0. In addition, to test the construct structure and confirm the teacher competency indicators, Confirmatory Factor Analysis (CFA) analysis was used with the help of LISREL 8.8 software. CFA was chosen because it can test the relationship between latent variables and indicators hypothesized in theoretical models.

The stages of implementation of this research include several interrelated phases. The first phase is the preliminary stage, which includes a needs analysis through literature review and field studies to identify problems and determine the main components of the evaluation model. The next stage is the development phase, where the prototype instrument and the initial model are compiled based on the results of the first stage of analysis. After initial development, a validation stage was carried out through FGD with experts and practitioners, followed by limited trials in several schools to assess the practicality and clarity of the instrument. Based on the results of the limited trials, revisions were made to the instruments and models, then continued with wider trials to test the reliability and validity of the model more comprehensively. This process ended with the product finalization stage, which is a competency-based mathematics teacher performance evaluation model that is ready to be implemented in a formal education environment.

The validity of the content of the instrument was evaluated through an expert validation process using the Aiken coefficient as a quantitative basis to measure consensus among assessors on the clarity, relevance, and measurability of the indicators used. The results of this validation are then used as a basis for the instrument revision process before further testing is carried out. Meanwhile, the reliability of the instrument was tested through internal consistency analysis using Cronbach's Alpha coefficient value, to ensure that all indicators have stable consistency in measuring the competence dimension of mathematics teachers.

Figure 1 visually presents the flow of the R&D research methodology applied in this study, from the identification of needs to the finalization of the evaluation model.

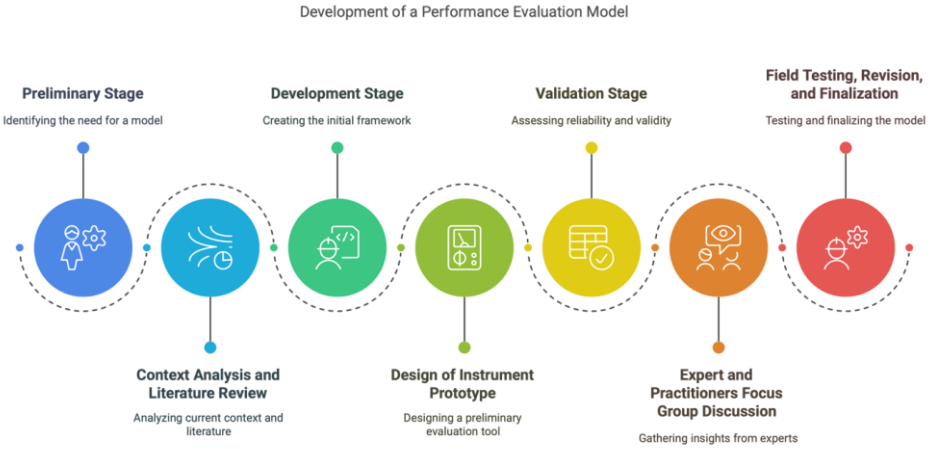

Figure 1. Stages of R&D Research Methodology in the Development of Mathematics Teacher Performance Evaluation Model

With a systematic approach and methodology and based on the principles of developing valid and reliable instruments, this research is expected to be able to produce a model of evaluation of the performance of mathematics teachers that can be a reference in policies to improve the quality of teachers and mathematics learning in Indonesia.

3. Results and Discussion

This study aims to develop a competency-based mathematics teacher performance measurement model by considering three main variables, namely mastery of mathematics teaching materials, ability to manage learning, and commitment in carrying out tasks. The findings were presented through descriptive analysis, teacher performance measurement, relationship with student learning outcomes, and the results of factor analysis in forming latent variables of mathematics teacher performance.

3.1 Descriptive Analysis of Mathematics Teacher Performance

The preliminary results of the descriptive analysis showed that in general, the performance of mathematics teachers in the aspect of learning planning was in the high category, with an overall average score of 85.78. This data indicates that most teachers have met the standards of lesson planning in accordance with good pedagogic principles. However, when viewed further by competency category, the personality component occupies the highest average score compared to other components such as pedagogic, professional, and social. This shows that mathematics teachers in general have strong integrity and personal responsibility in carrying out their professional duties.

In Figure 2, personality competencies reached an average score of 89, followed by pedagogic (84), professional (83), and social (77) competencies. These findings are consistent with previous studies that show that teachers' personal competence and internal motivation are often the main strengths in carrying out learning tasks (Ramli, 2015; Hermawansyah, 2019; Nuwa, 2020).

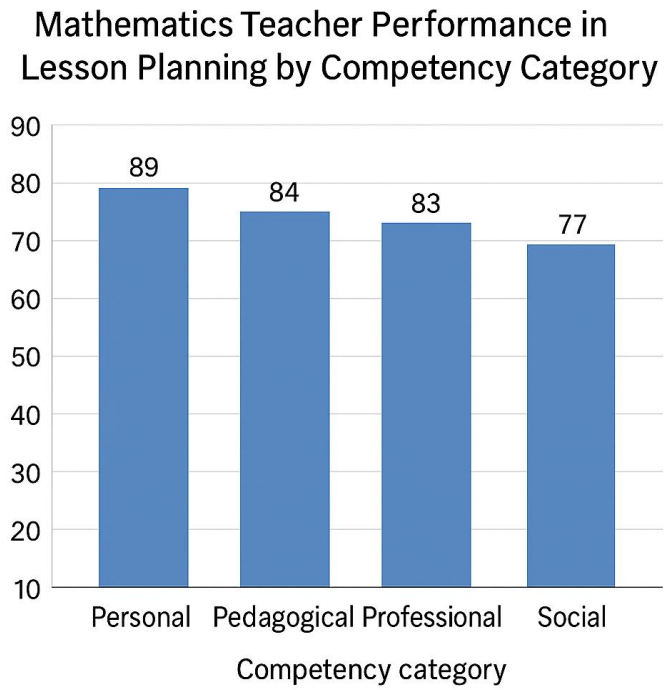

Figure 2. Mathematics Teacher Performance in Lesson Planning by Competency Category

Furthermore, the distribution of mathematics teacher performance categories shows that 45% of teachers are in the good category, 53% are adequate, and only 2% are in the poor category. This shows that although in general teacher performance is quite stable, there is still room for improvement, especially for groups of teachers who are categorized as underclass.

3.2 Correlation Between Teacher Performance and Student Achievement

The relationship between teacher performance and student learning achievement is also an important focus in this analysis. Data shows that 82% of students have achieved the Minimum Completeness Criteria (KKM) score, which is ≥75, while 18% of students have not achieved this score. This achievement strengthens the statement that teacher quality has a direct contribution to students' academic success, as stated by Abidin [33], Falentina [34], and Yandi et al. [35], that teacher factors are the main determinants of learning outcomes.

These findings are in line with the OECD report [52] which confirms that successful mathematics learning is largely determined by the role of teachers in conveying concepts in a meaningful and contextual way. Thus, the improvement in the teacher performance measurement model is expected to have a positive impact on overall student learning outcomes.

3.3 The Effectiveness of Performance Measurement Model

The teacher performance measurement management model developed in this study proved to be effective in improving the quality of mathematics learning, especially through three indicators: performance improvement, understanding improvement, and skill improvement in the learning process. The effectiveness of this model can be seen in the implementation of more structured and reflective learning, as reflected in the results of in-depth observations and interviews.

Teachers who were the subjects of the study reported that with clear indicators in the evaluation model, they were able to conduct more targeted self-reflection. This shows that the evaluation model is not only a measuring tool, but also a coaching instrument that encourages the professional growth of teachers [42][43].

3.4 Factors Influencing Mathematics Teacher Performance

In analyzing the factors that affect the performance of mathematics teachers, several key components that contribute to performance variation were found. These factors include self-management and basic teaching skills, coaching teaching quality, school culture and climate, and motivation to excel. These findings show that improving teacher performance depends not only on technical abilities alone, but also on contextual and psychological factors that shape teachers' attitudes and work ethic.

These findings support the research of Domu [44], which emphasizes the importance of commitment and mastery of the material as the main elements of mathematics teacher performance. These results emphasize that the evaluation model developed must include multidimensional indicators in order to capture the complexity of the teaching profession.

3.5 Construction of Latent Variable Model Using Factor Analysis

To construct a comprehensive model for measuring the performance of mathematics teachers, factor analysis was carried out using the Confirmatory Factor Analysis (CFA) approach. This analysis was used to identify the relationship between latent variables and measurable indicators consisting of mastery of mathematics teaching materials (X1), ability to manage learning (X2), and commitment to carrying out tasks (X3). This measurement model is based on the theory of factor analysis as formulated by Agung [53], which states that the general form of the equation of a latent variable is:

$$F1 = a11ZX1 + a12ZX2 + a13ZX3$$

In this equation, ZX1, ZX2, and ZX3 represent the standard scores of the three measurable variables, and F1 is the latent variable that describes the Math Teacher Performance Factor (KGM). The results of the CFA analysis show that the best models are:

$$F1 = 0.505\ ZX1 + 0.475\ ZX2 + 0.308\ ZX3$$

With an eigenvalue of 1.737 and a cumulative percentage of 57.92%, this model explains more than half of the variation in mathematics teacher performance. This means that the three main variables significantly contribute to the formation of teacher performance factors and can be used as a basis for the development of valid and reliable data-driven evaluation models [54][44].

This model also illustrates the importance of integrating the cognitive dimensions (mastery of teaching materials), affective (commitment), and pedagogical skills in measuring teacher performance. Thus, this model not only reflects real conditions in the field, but is also in line with the principles of teacher professional development within the framework of competency-based education.

3.6 Implication of the Model for Teacher Development and Policy

The application of this measurement model has a direct impact on the development of teacher potential and the improvement of the quality of mathematics learning in schools. In the context of education policy, this model can serve as a basis for designing a more objective and measurable academic supervision system. In addition, the results of teacher performance measurement also play an important role as a reflection on the four main competencies that must be possessed by a teacher, namely pedagogic, personality, professional, and social [20].

This model also allows the teacher coaching process to be more focused, as each aspect measured can be used to design a training program that suits the individual needs of teachers. This is in line with the principle of human resource development based on actual competence and performance.

3.7 Summary of Findings and Research Contributions

Overall, the results of this study show that the measurement of the performance of mathematics teachers can be carried out accurately through a model that considers the main dimensions of the teaching profession. The developed model has proven to have strong theoretical and empirical validity, as well as applicability in the context of junior secondary education. By combining quantitative approaches, expert evaluation, and field trials, this model can be used by educational institutions to improve the quality of mathematics learning on an ongoing basis.

The main contribution of this study is the preparation of a mathematical model for teacher performance evaluation based on three critical variables that have been tested in previous studies and strengthened by the results of factor analysis in this study. This model is not only a performance measurement tool, but also a means of professional development that encourages reflection, improvement, and pedagogical transformation.

3.8 Discussion

The results of this study show that the development of a competency-based mathematics teacher performance measurement model can make a significant contribution to improving teacher professionalism, learning effectiveness, and student learning outcomes. These findings support the previous statement that the quality of education is highly determined by the quality of teachers, especially in the context of mastery of materials, ability to manage learning, and professional commitment [44][20][21].

The performance of mathematics teachers who are in the high category with an average score of 85.78 in the aspect of learning planning shows that teachers have developed a good understanding of the curriculum structure and appropriate learning design. However, variations in competency components indicate inequality, with personality competencies scoring highest compared to pedagogic, professional, and social (see Figure 2). This reinforces findings in the literature that personality competencies, such as responsibility, integrity, and work ethics, are often more dominant aspects in teachers with formal certification backgrounds [22]. Although important, this competency cannot stand alone, since the effectiveness of teachers in managing the classroom and delivering material remains highly dependent on their pedagogic and professional abilities.

The distribution of teacher performance, which shows that 53% is in the category is sufficient, indicating that there is a gap between the potential and actualization of the teacher's role in learning practice. The fact that only 45% of teachers are in the good category and 2% are in the poor category shows that effective performance measurement must be able to identify systemic and personal weaknesses. In this context, competency-based evaluation can function as a more effective tool for reflection and coaching than the administrative approach alone, as criticized in conventional evaluation which has so far dominated academic supervision policies [42][43].

The correlation between teacher performance and student learning achievement, where 82% of students achieved KKM scores, reaffirmed the importance of teacher quality in determining academic achievement. This is in line with the findings in the PISA study which emphasizes that teacher effectiveness is one of the main predictors in students' mathematical literacy achievement [52]. The performance measurement model developed in this study not only assesses teachers based on administrative performance, but also on their ability to internalize contextual and meaningful learning approaches. Thus, this model can provide a more comprehensive picture of teachers' capacity in creating a learning environment that supports the achievement of KKM.

The effectiveness of the performance measurement model is also seen in improvements in three key aspects: teachers' understanding, skills, and performance in mathematics learning. These findings show that with an indicator-based evaluation structure, teachers are better able to plan, implement, and reflect on teaching and learning activities systematically. Previous literacy has shown that one of the main obstacles in mathematics learning is the lack of structure and consistency in the implementation of effective teaching strategies [10][11][12]. Therefore, strengthening the components of competency-based evaluation instruments, such as those offered in this study, is a very relevant solution to answer these problems.

In the context of factors that affect teacher performance, this study shows that variables such as self-management, teaching coaching, school culture, and achievement motivation have a significant role. These findings reinforce the view that teacher performance is not only individual but also contextual, where the work environment and institutional support affect overall teacher performance [33][34][35]. Thus, teacher performance improvement interventions should not only focus on personal training, but also on school environment reforms that support a positive learning climate.

One of the main contributions in this study is the construction of a mathematical model based on factor analysis that identifies latent relationships between three measurable variables, namely mastery of teaching materials, learning management ability, and commitment to carrying out tasks. The results of the Confirmatory Factor Analysis resulted in the F1 model = 0.505 ZX1 + 0.475 ZX2 + 0.308 ZX3, with an eigenvalue of 1.737 and a cumulative variant percentage of 57.92%. This figure shows that more than half of the variability in teacher performance can be explained by the three main variables measured. This is in line with competency-based performance measurement theory which states that professional success depends on a combination of cognitive, affective, and conative competencies [53][54].

The structure of the model is also consistent with the approach in the development of construct-validity-based evaluation instruments, where the theoretical dimension of the concept of "mathematics teacher performance" is translated into measurable observational indicators. By adopting this approach, the research offers not only practical solutions but also a methodological contribution to the development of evaluation tools in education. The validity and reliability of the instruments tested through the Aiken test and the internal consistency also reinforce the claim that this model can be used in a broader context, both for formative and summative evaluations.

The discussion also needs to be directed to the implications of using the model in education policy and teacher professional development. In the context of Government Regulation Number 19 of 2005, which emphasizes that teachers are the main agents of learning, the evaluation of teachers should reflect all aspects of the competencies required by the regulation. The evaluation model developed in this study has included four competency domains—pedagogical, personality, professional, and social—as the basis for measurement. This makes the model in line with the national normative framework and at the same time answers criticism of teacher evaluations that are partial.

The use of this model also provides practical benefits in human resource management in the education sector. With accurate and objective measurements, the school or education office can identify the specific weaknesses of each teacher and design a more targeted coaching program. In the long run, this will improve the efficiency of teacher training and the overall quality of education. This is in line with the data-driven decision-making approach that has long been advocated in modern education management.

Additionally, it is important to highlight that although this model has high empirical validity, there are several challenges in its implementation in the field. Among them are limited resources to conduct direct observation, the need for training for evaluators, and the resistance of some teachers to the indicator-based evaluation system. Therefore, the implementation of this model needs to be accompanied by a good communication strategy, technical training for evaluators, and strengthening a school culture that supports reflection and continuous improvement. It is important that evaluation is not perceived as a mere control mechanism, but as an integral part of the professional development process.

In the context of the international literature, this research also enriches the global discourse on teacher performance measurement by providing a locally based perspective but using a methodological approach that is compatible with global practices. The emphasis on instrument validation, a combination of qualitative and quantitative approaches, and the integration of theory and practice are principles that are in line with the recommendations of educational evaluation experts such as Gravemeijer and Cobb [55], and Van Eerde [56], who emphasize the importance of contextual, theoretical, and applicative instruments in supporting educational transformation.

Thus, this discussion confirms that the competency-based mathematics teacher performance measurement model developed in this study has a strong theoretical basis, supporting empirical evidence, and broad implementation potential. The model also shows the flexibility to adapt in a variety of school contexts with different characteristics and needs.

4. Conclusions

This study developed a competency-based evaluation model to measure the performance of mathematics teachers at the secondary education level. The findings demonstrated that the model, incorporating measurable variables such as subject mastery, instructional management, and professional commitment, is both valid and reliable. The confirmatory factor analysis revealed that these three variables significantly contribute to a latent construct of teacher performance, with a cumulative explanatory power of 57.92%. This result reinforces the notion that teacher performance is not merely determined by one-dimensional skills but emerges from the integration of cognitive, pedagogical, and affective competencies.

The model proved effective in distinguishing performance levels across diverse teaching environments and identifying specific areas for professional development. It also correlated positively with student achievement, affirming the model's practical value in driving educational outcomes. The inclusion of context-sensitive components such as school climate and intrinsic motivation further supports its application in real-world educational settings.

This study contributes to the existing body of knowledge by offering a structured, data-driven tool for evaluating mathematics teacher performance that aligns with national education standards and international assessment principles. It bridges theoretical constructs and classroom practices, enhancing both teacher supervision and instructional quality. Future research could explore the adaptation of this model in other subject areas or educational levels and examine its longitudinal impact on teacher professional growth and student learning trajectories.

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