TADBIR JURNAL STUDI MANAJEMEN PENDIDIKAN
http://journal.iaincurup.ac.id/index.php/JSMPI
DOI: http://dx.doi.org/10.29240/jsmp.v10i1.16174

Data-Based Teacher Continuing Professional Development Governance Model and Evaluation Protocol for Intelligent Triangulation System Implementation in Elementary Schools

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Abstract: The problem of pedagogical and professional competence of elementary school teachers is still high and the use of learning data is ineffective. The urgency of this research is because teachers are data-based decision makers, while the practice of Continuous Professional Development (CPD) in elementary schools is still administrative and lacks real impact. The novelty is the development of a data-based teacher personal knowledge governance model integrated with the Intelligent Triangulation System (ITS), which combines student learning outcome data, learning observations and teacher reflections in a single decision-making framework. The objectives are to analyse the initial condition of teacher competence, develop and implement the model, test its effectiveness, and compile a continuous evaluation protocol. The research approach is a mixed method with a quantitative quasi-experimental design. The research sample consisted of 37 elementary school teachers, 37 students, 3 principals, and 3 supervisors. Data collection techniques include pre-test, post-test, observation, interviews, documentation and ITS usage logs. Data analysis was carried out descriptively, inferentially (paired sample t-test) and triangulation. The results showed an increase in pedagogical competence by 13.85% and professional competence by 14.65% ($p<0.05$), as well as an increase in student literacy by 13.40% and numeracy by 14.15%. The research findings indicate that the data-driven model is effective in building reflective practices and objective decision-making. In conclusion, the data-driven teacher knowledge governance model with ITS has proven effective, systematic, and sustainable in improving competence. The limitations of the study are that the trial was only conducted in a limited location and there was no control group.

Keywords: Management; Data-Based Decision Making; Teacher Professional Development; Continuing Professional Development; Intelligent Triangulation System; Elementary School.

INTRODUCTION

Current technological advances pose new challenges for educational management worldwide to address the ever-growing complexities of change (Tamadoni & Hosseingholizadeh, 2024). Improving the quality of education through technology training for teachers is one of the new challenges (Zambrano-romero et al., 2025). Teachers are the spearhead in the learning process, they must be able to adapt to the demands of the times, integrate technology, and apply various innovations to the learning process (AlSagri & Sohail, 2024). To support this, many countries have implemented structured, data-driven continuing professional development (CPD) systems (Nguyen et al., 2024). According to a UNESCO report, countries like Finland, Singapore, and Canada prioritize teacher development. For example, Finland allocates approximately 7-10% of its national education budget to teacher training and professional development programs (Karila & Kupila, 2023). Singapore, through its Continuing Professional Development (CPD) program, 85% of teachers participate in training annually, which contributes to improved student learning outcomes.

The 2022 OECD Programme for International Student Assessment (PISA) report shows that countries that implement data-driven professional development and continuous assessment systems tend to achieve higher scores in reading, writing, mathematics, and science. For example, Singapore's average score of 558 is significantly higher than the OECD average of 487 (OECD, 2021). As technology and educational needs evolve, various governance models for teacher professional development are being implemented internationally. Data-driven and continuous assessment models, such as the Data-Driven Teacher Professional Development (DTPD) model currently in use, are being implemented (OECD., 2019). This model integrates student learning outcome data, classroom observations, and teacher feedback to design relevant and effective training programs (Gao, 2025).

Indonesia continues to face significant challenges in improving the quality of education through teacher competency development (Susanto et al., 2019). Data from the Teacher and Education Personnel Development Agency (BPPT) in 2023 showed that 65% of Indonesia's 3.9 million teachers actively participated in the Pedagogical Competency Development Program (PCDP) (Susanto & Rozali, 2022). However, in fact, only 40% of teachers who participated in the training felt real benefits in improving their pedagogical and professional competence (Bagus & Puja, 2024). The 2022 Teacher Performance Evaluation showed that the level of pedagogical and professional competence among Indonesian teachers was 60%-70% in the moderate category (Susanto et

al., 2025). This data indicates that many teachers still need to develop their competencies through more structured and data-driven professional development programs. A report from the Ministry of Education, Culture, Research, and Technology shows that the success rate of teacher-led and data-driven knowledge management programs continues to experience inconsistencies in implementation, measurement, and evaluation in the field (Maharani et al., 2024). This problem also often arises in education, especially at the elementary school level (Allman et al., 2024)

National Education Data shows that 30% of elementary schools in remote and less developed areas have not implemented technology and data-based learning systems (Farisia et al., 2025). This indicates a gap in student competency achievement and the overall quality of learning in Indonesia. Therefore, a knowledge management governance model is needed that integrates effective, data-driven assessment designs and plans (Lin et al., 2024). Another fact is that teachers in Indonesia show significant gaps in terms of competence and access to training (Artanti et al., 2025). According to 2023 data from the Center for Manager Development and Empowerment, 25% of teachers in underdeveloped and remote areas have not received adequate training (Shanmugam et al., 2025). This situation is exacerbated by the absence of an integrated monitoring and evaluation system, making it difficult to measure the effectiveness of cognitive development programs (Antonius et al., 2024). Developing a data-driven governance model is crucial. This model aims to provide a systematic and measurable framework for developing, implementing, and disseminating competency development programs.

The Data-Based Teacher Personal Knowledge Governance Model Theory designs a Teacher Personal Knowledge Governance Scheme and assessment protocol for the implementation of the Intelligent Triangulation System in elementary schools that incorporates various concepts that support the development and evaluation of the system. The data-driven decision-making theory is fundamental, as decisions are based on accurate data to improve the quality of learning and teacher effectiveness (Mukred et al., 2024). The theory of Continuing Professional Development (CPD) supports the concept of Teacher Personal Knowledge as a continuous process to improve teacher effectiveness through data as the basis for planning and evaluation (Asmare, 2025). Systems theory is also important, as Smart is part of a complex educational system that requires coordination and integration across various components of data management and decision-making. Furthermore, Everett Rogers' theory of educational innovation emphasizes the importance of adopting technology and innovation to improve educational quality through a planned and systematic process (Rogers & Everett, 1962). Educational program and policy evaluation

theories, such as the CIPP (Context, Input, Process, Product) model, are relevant for designing effective evaluation protocols to assess the success of ITS system implementation (Stufflebeam & Coryn, 2007). By integrating this theory, this data-driven governance model is expected to support better decision-making, is assumed to increase teacher effectiveness, and ensure the successful implementation of the Intelligent Triangulation system in elementary schools.

This research is urgently needed in the era of globalization and rapid digital technology development, as improving the quality of education has become an undeniable necessity. Teachers, as key actors in the learning process, are required to possess adaptive, data-driven, and student-specific pedagogical and professional competencies. Many developed countries have demonstrated that continuous, data-driven teacher competency development contributes to improved learning quality and outcomes. However, teacher competency development in Indonesia still faces many challenges, such as low participation in professional development programs, unequal training opportunities across regions, and weak monitoring and evaluation systems. This situation requires a more systematic and measurable model for managing teacher competency development, with a focus on the continuous use of data, particularly at the elementary school level. The research gap stems from the disparity between theory, expectations, and reality. While training models can improve learning outcomes, in practice, implementation has not been fully implemented, resulting in educational expectations not being met. The novelty of this research lies in the development of a data-driven model for managing teachers' personal knowledge, integrated with an intelligent triangulation system. This model not only utilizes data from student learning outcomes, classroom observations, and teacher reflections but also organizes them into a systematic framework for decision-making and evaluation. By focusing on improving elementary schools.

Research questions: 1) How is the development of pedagogical and professional competencies of elementary school teachers in data-based learning? 2) How can the design of a data-based teacher personal knowledge governance model integrate with an intelligent triangulation system be developed systematically? 3) How is the implementation process of a data-based teacher personal knowledge governance model in supporting decision making? 4) To what extent is the effectiveness of a data-based teacher personal knowledge governance model in improving teachers' pedagogical and professional competencies? 5) What is the appropriate evaluation protocol to measure the sustainability and success of the implementation of a data-based teacher competency development model? So the objectives of the research are to 1) Analyze the conditions and problems of developing pedagogical and professional competencies of elementary school teachers in utilizing learning

data, 2) Analyze the development of a data-based teacher personal knowledge governance model integrated with an intelligent triangulation system according to the needs of elementary schools, 3) Analyze the results of the implementation of a data-based teacher personal knowledge governance model in supporting decision making for teacher competency development, 4) Test the effectiveness of a data-based teacher personal knowledge governance model in improving the pedagogical and professional competencies of elementary school teachers, 5) Develop a systematic, measurable, and sustainable evaluation protocol to assess the success and impact of the implementation of a data-based teacher competency development model.

RESEARCH METHODOLOGY

The research method used is a mixed methods approach (Kumar & Kushwaha, 2025). Quantitative and qualitative approaches were chosen to provide a comprehensive understanding of the effectiveness of the Data-Based Teacher Professional Development Governance Model supported by the Intelligent Triangulation System (ITS). The quantitative approach, through a quasi-experimental design with a pre-test to post-test scheme, was used to measure changes in teachers' pedagogical and professional competencies and early indicators of student learning outcomes after the model's implementation. Meanwhile, a qualitative approach was used to in-depth explore the implementation process, user experience, and model application through observation, interviews, and documentation studies. The experimental method provides a strong empirical basis for assessing the model's effectiveness, while qualitative data enriches the interpretation of the findings and helps explain supporting and inhibiting factors in implementation.

The study population consisted of all stakeholders involved in the implementation of teacher professional development in elementary schools. The research sample was determined at Karang Tengah Elementary School as the initial implementation partner school. The study participants numbered 80 people, consisting of 37 teachers from three different schools, 37 students from three classes, 3 principals from three schools, and 3 school supervisors, all of whom were directly involved in the data-driven teacher professional development governance cycle. The sampling technique was purposive sampling, with criteria for active involvement in the use of ITS, the implementation of professional development and the monitoring and evaluation function of learning by teachers.

Quantitative data collection techniques used pre- and post-tests and measurement instruments. The tests measured changes in teachers' pedagogical and professional competencies before and after the implementation of the data-

driven CPD model. Data were also collected through student diagnostic assessments, which included literacy, numeracy, and early indicators of learning achievement. The test instruments were developed based on validated competency indicators and adapted to the research objectives. Other data were collected through ITS system usage logs, which recorded the frequency of access, the types of recommendations used, and the patterns of system use by teachers and principals. Qualitative data were collected through observation, interviews, and documentation studies. Direct observation of the learning process and implementation of CPD in schools using a differentiated learning practice rubric. Observations were used to obtain empirical data regarding the implementation of the model, the consistency of ITS recommendations, and changes in teacher learning practices in the classroom. Semi-structured interviews were conducted with teachers, principals, and school supervisors. The interviews were conducted to explore in-depth user experiences, perceptions of ITS usability, the level of model acceptance, and obstacles and opportunities in implementing data-driven CPD governance. Documentary evidence was collected as supporting data in the form of CPD planning documents, CPD blueprints, academic supervision reports, and school policies related to teacher professional development. This documentation serves to verify and strengthen the findings from tests, observations, and interviews.

Table 1. Variables, Indicators and Research Items

Variables/Aspects.	Indicators	Indicator Items
Teacher Pedagogical Competence.	Learning Planning	1. Preparation of lesson plans based on student learning outcomes data 2. Formulation of learning objectives based on student needs 3. Integration of diagnostic assessments in planning 4. Selection of differentiated learning strategies 5. Adaptation of materials to student characteristics 6. Utilization of literacy and numeracy data 7. Integration of learning technology 8. Alignment of plans with ITS recommendations
	Learning Implementation	1. Implementation of data-driven learning 2. Use of assessment results for differentiation 3. Adaptive classroom management 4. Implementation of active and collaborative strategies 5. Utilization of media and technology 6. Responding to student learning needs 7. Consistency with the lesson plan 8. Implementation of ITS recommendations in the classroom
	Learning Evaluation	1. Use of formative and summative assessments 2. Analysis of student learning outcomes 3. Data-based feedback 4. Utilization of evaluation results for improvement 5. Documentation of assessment results 6. Alignment of evaluation with objectives 7. Teacher learning reflection 8. Integration of evaluation results into ITS
Teacher	Material	1. Mastery of subject concepts 2. Relevance of material to real-world contexts

Professional Competence.	Mastery	3. Updating subject knowledge 4. Utilization of the latest learning resources 5. Accuracy of material delivery 6. In-depth understanding of material based on student data 7. Integration across subjects 8. Relevance of material to student needs
	Continuing Professional Development (CPD)	1. Active participation in CPD activities 2. Utilization of ITS data for CPD 3. Professional learning independence 4. Collaboration in teacher learning communities 5. Data-based self-reflection 6. Application of CPD results in learning 7. Consistency in following the CPD cycle 8. Documentation of competency development
Implementation of the Intelligent Triangulation System (ITS).	Data Utilization	1. Input of student learning outcome data 2. Utilization of classroom observation data 3. Use of teacher reflection data 4. Accuracy and completeness of data 5. Consistency of data updates 6. Data analysis by teachers 7. Data integration in decision-making 8. Sustainability of data use
	Decision-Making Support	1. ITS recommendations for learning 2. ITS recommendations for CPD 3. Suitability of recommendations to teacher needs 4. Clarity of information presented 5. Ease of system access 6. Speed of system response 7. Level of user trust 8. Impact of recommendations on teacher practice
Effectiveness of the Data-Based CPD Governance Model.	Impact on Teachers	1. Improved pedagogical competence 2. Improved professional competence 3. Changes in learning practices 4. Improved data-based reflection 5. Consistent use of ITS 6. Teacher satisfaction with the model 7. Motivation for self-development 8. Sustainability of CPD practices
	Impact on Student Learning	1. Improving student literacy 2. Improving student numeracy 3. Student involvement in learning 4. Differentiation of learning 5. Suitability of learning to student needs 6. Stability of learning outcomes 7. Improvement of diagnostic assessment results 8. Consistency of improving learning outcomes

The data analysis technique in this study began with quantitative data processing, followed by qualitative data analysis, and ended with the process of integrating (triangulating) the analysis results. Quantitative data analysis used descriptive statistics, by analyzing the results of the pre-test and post-test of teachers' pedagogical and professional competencies. Descriptive statistical analysis was used to determine the average value, percentage, standard deviation, and trend of score changes before and after model implementation. Furthermore, inferential statistical tests were used to measure the significance of differences in pre-test and post-test results, using paired sample t-tests. Quantitative analysis was also applied to student diagnostic assessment data to

assess improvements in learning outcomes as an early indicator of the impact of model implementation. ICT usage log data was also analyzed descriptively to identify system utilization patterns, access frequency, and the types of recommendations most frequently used by teachers and principals. Meanwhile, qualitative data were also analyzed in stages. Observational data were analyzed using a learning practice rubric and a CPD implementation observation sheet to assess the consistency of the application of ITS recommendations in learning and professional development activities. Interview data were analyzed using thematic analysis techniques through the stages of data reduction, coding, categorization, and extraction of main themes. This process aims to uncover perceptions, experiences, levels of acceptance, and supporting and inhibiting factors in the implementation of a data-driven CPD governance model. Documentation data was analyzed by matching document content with quantitative and qualitative findings to strengthen the validity of the research results. The final stage of data analysis was conducted through method and source triangulation, namely by comparing and integrating quantitative and qualitative findings. This process aims to ensure consistency of results, increase data validity, and produce more objective and in-depth conclusions regarding the effectiveness, sustainability, and relevance of the teacher CPD governance model.

RESULTS AND DISCUSSION

In this study, the results showed a significant increase in teachers' pedagogical and professional competencies after implementing a data-based performance management model. The following are the research results and discussion.

Table 2. Results of the Initial and Final Tests of Teacher Competency

Competency Variables.	Testing Stage	N	Average	Percentage	Standard Deviation	Trend Change
Pedagogical Competence.	Pre-Test	37	68.45	68.45	6.82	-
	Post-Test	37	82.30	82.30	5.94	Increasing
	Changes	-	13.85	13.85%	-	Positive
Professional Competence.	Pre-Test	37	70.10	70.10	7.15	-
	Post-Test	37	84.75	84.75	6.02	Increasing
	Changes	-	14.65	14.65%	-	Positive

Table 2 shows the results of pedagogical competence. The mean score of the teachers increased from 68.45% in the pre-test to 82.30% in the post-test, a difference of 13.85 points or 13.85%. The decrease in the standard deviation from 6.82 to 5.94 indicates that the increase in competence was not individual but rather more uniform among the teachers. Significant improvement was seen in professional competence. The mean score in the pre-test increased from 70.10% to 84.75% in the post-test, an increase of 14.65%. The standard deviation decreased from 7.15 to 6.02, indicating a steady increase in professional competence. With an increase of more than 13% in both competencies, the post-test results were in the "good to very good" category.

Table 3. Results of Inferential Statistical Test of Teacher Competence Pre-Test and Post-Test

Competency Variables	N	Pre-Test Average	Post-Test Average	Mean Difference	t count	df	Sig. (p-value)	Category
Pedagogical Competence	37	68,45	82,30	13,85	11,42	36	0,000	Significant
Professional Competence	37	70,10	84,75	14,65	12,18	36	0,000	Significant

Table 3 shows the results of the inferential statistical test using a paired sample t-test to compare the pre-test and post-test scores of teacher competency with a mean difference of 13.85 points. The calculated t-value = 11.42 at df = 36 degrees of freedom, and a significance value of p = 0.000 (<0.05), indicating that the difference is statistically significant. This confirms that the increase in pedagogical competency did not occur by chance, but rather was a real impact of the model implementation. For professional competency, the mean pre-test and post-test scores, with a mean difference of 14.65 points. The calculated t-value = 12.18, df = 36, and p = 0.000 also indicate a highly significant difference.

These findings indicate that the use of learning data, teacher reflections, and ITS system recommendations can improve the planning, implementation, and assessment processes of learning, while simultaneously promoting teachers' ongoing professional development. A data-driven CPD model, integrated with an intelligent triangulation system, effectively enhances teachers' pedagogical and professional competencies simultaneously. These findings are consistent with data-driven decision-making theory, which states that data-driven decisions improve the effectiveness of teacher learning and performance (Barthakur, 2025). The theory of ongoing professional development supports these findings,

which views competency development as a process of continuous reflection and evaluation (Arenas-martija, 2025). The findings align with systems theory, data integration, technology, and professional practices that form a sustainable ecosystem in teacher development (Amemasor et al., 2025). This finding is in line with previous research in continuing professional development (CPD) practices that shows that a data-driven teacher development approach improves competency and the quality of learning (Isnaeni & Budiman, 2025). Previous research also showed increases in teacher competency ranging from 10% to 15% after data-driven interventions (Lee et al., 2024).

Table 4. Student Diagnostic Assessment Results

Assessment Aspect.	Measurement	N	Average Score	Percentage	Standard Deviation	Trend Change
Literacy.	Initial (Pre)	37	65.20	65.20	7.48	-
	Final (Post)	37	78.60	78.60	6.31	Increasing
	Change	-	13.40	13.40%	-	Positive
Numeracy.	Initial (Pre)	37	63.75	63.75	8.05	-
	Final (Post)	37	77.90	77.90	6.88	Increasing
	Change	-	+14.15	14.15%	-	Positive

Table 4 shows student diagnostic assessments of literacy and numeracy before and after the implementation of a data-driven CPD governance model supported by the Intelligent Triangulation System (ITS). In the literacy aspect, the mean student score increased from 65.20% in the pre-test to 78.60% in the post-test, representing a 13.40-point increase. The decrease in the standard deviation from 7.48 to 6.31 indicates that the improvement in literacy was not limited to a few students, but was relatively evenly distributed across the participant group. In the numeracy aspect, a similar pattern of improvement was also observed. The mean score increased from 63.75% to 77.90%, representing a 14.15-point difference. The standard deviation decreased from 8.05 to 6.88, indicating a consistent increase in numeracy achievement, a positive change, and in the good category.

This finding is in line with the theory of data-driven decision-making, which states that the systematic use of learning data can improve teaching effectiveness and student learning outcomes (Ncube & Ngulube, 2025). The theory of continuing professional development supports this research that continuous improvement of teacher capacity will have an impact on improving classroom learning practices (Rahmi & Rassanjani, 2025). This finding is also

consistent with previous research, improving student learning outcomes after implementing data-based learning and structured teacher professional development (Marini et al., 2025). With an increase in literacy of 13.40% and numeracy of 14.15% in this study, it strengthens the evidence that the data-based CPD model is effective in improving the quality of learning for elementary school students.

Table 5. Intelligent Triangulation System (ITS) Usage Log Results

ITS Usage Indicators.	User	Average Frequency	Percentage (%)	Utilization Category
Weekly system access.	Teacher	4.6 times	76.7	High
	Headmaster	3.8 times	63.3	Medium-High
Use of learning recommendations.	Teacher	82 times	78.4	Dominant
Use of CPD recommendations.	Teacher	69 times	65.8	High
Access to student diagnostic reports.	Teacher & KS	91 times	86.5	Very Dominant
Input of reflection and observation data.	Teacher	57 times	54.3	Medium
Most frequently used recommendation types.	-	-	-	Differentiated Learning and Data-Based CPD

Table 5 shows the usage patterns of the Intelligent Triangulation System (ITS). Teachers used the system an average of 4.6 times per week, or 76.7%, a high rate, while administrators used it an average of 3.8 times per week, or 63.3%, a moderate to high rate. This indicates that teachers, as the primary operational users, utilize the Intelligent Triangulation System (ITS) extensively for learning and personal knowledge development. Teachers recorded 82 instructional recommendations, or 78.4%, a typical usage rate, indicating that ITS recommendations are actively used in classroom practice. Concurrently, personal knowledge development (CPD) recommendations were used 69 times (65.8%), a high rate, further highlighting the role of the Intelligent Triangulation System (ITS) in supporting teacher professional development. Accessing student diagnostic reports was the most frequent activity, occurring 91 times (86.5%),

reflecting a strong tendency toward data-driven decision-making. Conversely, the integration of reflective and observational data was in the moderate category at 54.3%, indicating the need to foster a culture of ongoing reflection.

Table 6. Coding of Qualitative Data Analysis of the Implementation of the Data-Based CPD Governance Model

Data Sources	Open Coding	Category (Axial Coding)	Main Themes	Description of Findings
Learning observations	Data-driven learning, differentiation, use of diagnostic assessments	ITS-based learning practices	Consistency of ITS implementation in learning	Teachers consistently apply ITS recommendations in lesson planning and implementation.
CPD observations	Data-driven discussion, professional reflection, referral to ITS recommendations	Data-based CPD implementation	Strengthening relevant and contextual CPD	CPD activities are more focused on teachers' real needs and evidence-based.
Teacher interviews	Easy to use, facilitates reflection, and is relevant to needs	Perceived system benefits	Positive acceptance of ITS	Teachers consider ITS beneficial in improving the quality of learning and self-development.
Principal/ supervisor interviews	Objective monitoring, data-driven decisions	Managerial support	Data-driven leadership	ITS supports more objective and measurable CPD decision-making.
Teacher interviews	Time constraints, technology adaptation	Implementation barriers	Initial technical challenges	Obstacles are temporary and do not hinder the sustainability of the model.
CPD document	Data-driven CPD documents,	Document-practice	Validation of research	Documents support and strengthen

ation	aligned with observation results	alignment	findings	quantitative and qualitative findings.
Teacher reflection journals	Data-driven reflection, continuous improvement	Reflective practice	Culture of professional reflection	Habits of systematic, data-based reflection are formed.
Supervision reports	Improving the quality of learning	Implementation impact	Effectiveness of the CPD model	The data-based CPD model is considered effective in improving learning practices.

Table 6, coding and findings from lesson observations, shows that teachers consistently apply ITS recommendations in lesson planning and implementation, particularly through the use of diagnostic assessments and differentiated learning strategies. Professional development activities are more focused because teacher discussions and reflections are based on empirical data, making CPD more relevant and contextual. Interviews with teachers indicate a positive level of acceptance of ITS, as the system is perceived as easy to use and facilitates professional reflection. Managerial support is also strong, with principals and supervisors using ITS to make more objective and measurable CPD decisions. While there were initial challenges such as time constraints and technological adaptation, these were temporary. Analysis of documentation, reflections, and supervision reports strengthened the validity of the findings through triangulation, while also demonstrating the development of a culture of professional reflection and improved quality of teaching practice.

Developing the Pedagogical and Professional Competencies of Elementary School Teachers

The initial development of elementary school teachers' pedagogical and professional competencies was found to be adequate. The main problem identified was the limited systematic use of learning data in planning, implementing, and evaluating learning. Teachers tended to use data only as an administrative supplement, not as a basis for pedagogical decision-making. Meanwhile, data-based reflection and the integration of diagnostic assessment results into professional development were still suboptimal. This finding contradicts the theory of data-driven decision-making, which states that the quality of learning decisions is largely determined by educators' ability to interpret and use data sustainable (Masumbika & Patrick, 2024). This initial

finding also contradicts the theory of Continuing Professional Development (CPD), this condition shows that the teacher competency development cycle has not been running in a reflective and sustainable manner (González et al., 2025). However, Consistency with previous research is seen in studies by the OECD and UNESCO, which report that teachers face similar challenges, particularly low data literacy and weak technology-based support systems for students (Roshid & Haider, 2024). The findings of this study contradict research that says that teacher training often does not have a significant impact because it is not based on real needs that can be measured through data (Farah et al., 2025).

A data-driven model for teachers' personal knowledge governance

This study presents a data-driven model for teachers' personal knowledge governance integrated with the Intelligent Triangulation System (ITS) in elementary schools. This model combines three primary data sources: student learning outcomes, learning observations, and teacher reflections, into a systematic decision-making framework. This model is designed to adapt to the characteristics of elementary schools, including differentiated learning needs and resource constraints. The developed model is based on systems theory, which views teacher competency development as an integrated ecosystem consisting of data, technology, teaching practices, and school policies (Amemasor et al., 2025). Personal Knowledge Management Theory supports the organization of individual teacher knowledge while remaining connected to the school system. ITS integration strengthens analytical functions and evidence-based recommendations (Almaghrabi et al., 2024). Consistency with previous research is seen in the Data-Driven Teacher Professional Development (DTPD) model (Avila-garzon & Bacca-acosta, 2025). However, this study is novel because it adapts this approach to the Indonesian elementary school context and integrates it with teachers' personal reflection mechanisms. However, the findings of this study are inconsistent with those of previous studies that focused on centralized training, whereas this model emphasizes teacher independence in managing data-driven knowledge (Ugwu et al., 2025).

The implementation mechanism of the knowledge governance model supports decision making.

The implementation mechanism of this model is carried out through a continuous cycle that includes data collection, analysis through ITS (Student Competency Test), recommendation development, implementation of learning and continuing professional development (CPD), and reflection and evaluation. Teachers actively enter student learning outcome data, conduct reflection, and use ITS recommendations in lesson planning and implementation. Principals

and supervisors use the same data for more objective managerial decision-making. This mechanism aligns with the theory of data-driven decision-making, which emphasizes the importance of integrating micro (classroom) and macro (school) data in professional development (W. Khan et al., 2025). Educational innovation theory explains that adoption rates of models increase because the systems are designed to be easy to use, relevant to teachers' needs, and provide immediate benefits (Wong & Ling, 2024). These findings are consistent with previous research showing that the successful implementation of data-driven models is largely determined by clear workflows, school leadership support, and active teacher engagement (Cabral et al., 2025). A system that provides practical, data-driven recommendations is more effective than statistical reports alone.

Effectiveness of Teachers' Personal Knowledge Management Model

The effectiveness test results showed significant improvements in teachers' pedagogical and professional competencies. These findings were reinforced by improvements in the quality of instructional practices and the consistent use of data in teacher reflections. The effectiveness of this model can be explained through CPD theory, which states that developing competencies based on reflection and data results in more meaningful changes in practice. In adult learning theory (andragogy) supports the finding that teachers are more motivated when professional learning is relevant to their real needs (Elsawah, 2025). Consistency with previous research is seen in studies reporting increased teacher competency after implementing a data-driven approach (Abdulkadir et al., 2025). The results of this study fall within this range, strengthening the empirical validity of the model (M. Khan et al., 2024). The difference is that this study integrates personal knowledge management and an intelligent triangulation system, resulting in a more comprehensive impact.

Impact of Implementing a Data-Based Teacher Competency Development Model

This study yielded a CIPP-based evaluation protocol (Context, Input, Process, Product) adapted for the context of data-driven elementary school teacher competency development. This protocol includes quantitative indicators (teacher competency scores, student learning outcomes, and ICT usage records) and qualitative indicators (observations, interviews, and teacher reflections). Evaluation is conducted continuously to ensure the model's sustainable impact. The protocol's theoretical basis stems from educational program evaluation theory, which emphasizes the importance of formative and summative evaluation in ensuring program quality and sustainability (Jamieson et al., 2025). Furthermore, an evidence-based evaluation approach ensures that every development decision is based on valid and reliable data (Raitskaya &

Tikhonova, 2024). Consistency with previous research is seen in CPD evaluation practices in developed countries that use multi-source and impact-oriented indicators (Smiliotopoulos et al., 2024). However, this research makes a novel contribution by integrating evaluation directly into the ITS system, so that evaluation is not merely external but becomes part of the teacher's professional learning cycle (Keryan et al., 2025).

CONCLUSION

The conclusion of this study is that the development of pedagogical and professional competencies of elementary school teachers requires a more systematic, data-driven, and sustainable approach, as found in this study. Initial conditions indicated that teacher competencies were still adequate, with less-than-optimal utilization of learning data as a basis for pedagogical decision-making and professional development. This confirms the gap between the demands of data-driven learning and the practice of teacher competency development in the field. By testing a data-driven model for teachers' personal knowledge management integrated with the Intelligent Triangulation System (ITS), the learning process was improved and had a positive impact on student development. This model was able to integrate student learning outcome data, learning observations, and teacher reflections into a single decision-making framework that was adaptive to the needs of elementary schools. The implementation of this model followed a continuous cycle that encouraged teachers, principals, and supervisors to use data collaboratively and objectively in competency development. Effectiveness testing showed that the model's implementation significantly improved teachers' pedagogical and professional competencies. This improvement occurred evenly, accompanied by positive changes in learning practices and a culture of professional reflection. In addition, indirect impacts were also seen in improving student learning outcomes, particularly literacy and numeracy. This research also produced a CIPP-based evaluation protocol that is systematic, measurable, and sustainable, and directly integrated with ICT systems. The findings of this study contribute theoretically and practically to the development of a data-driven teacher competency management model that is relevant, contextual, and has the potential for broader application in improving the quality of student education in elementary schools.■

REFERENCES

Abdulkadir, J., Hassan, A., Khadar, M., Abdi, T., Hassan, Y., & Axmed, M. (2025). International Journal of Educational Research Open Machine learning-driven analysis of academic performance determinants :

Geographic , socio-demographic , and subject-specific influences in Somaliland ' s 2022 – 2023 national primary examinations. *International Journal of Educational Research Open*, *8*(October 2024), 100426.1-9. https://doi.org/10.1016/j.ijedro.2024.100426

Allman, B., Kimmons, R., Wang, W., Bao, H., Rosenberg, J. M., & Koehler, M. J. (2024). Trends and Topics in Educational Technology, 2024 Edition. *TechTrends*, *68*(3), 402–410. https://doi.org/10.1007/s11528-024-00950-5

Almaghrabi, H., Soh, B., & Li, A. (2024). SoK : The Impact of Educational Data Mining on Organisational Administration. *Information*, *15*(11), 1–33. https://doi.org/10.3390/info15110738

AlSagri, H. S., & Sohail, S. S. (2024). Evaluating the role of Artificial Intelligence in sustainable development goals with an emphasis on "quality education". *Discover Sustainability*, *5*(1), 1-26. https://doi.org/10.1007/s43621-024-00682-9

Amemasor, S. K., Oppong, S. O., Benuwa, B., & Essel, D. D. (2025). A systematic review on the impact of teacher professional development on digital instructional integration and teaching practices. *Frontiers in Education*, *23*(May), 1–14. https://doi.org/10.3389/feduc.2025.1541031

Antonius, F., Janani, S., Santosh, K., Shweihat, S. N., Alshammry, N., Venkata, J., Ramesh, N., & El-ebiary, Y. A. B. (2024). Enhancing AI interpretation and decision-making : Integrating cognitive computational models with deep learning for advanced uncertain reasoning systems. *Alexandria Engineering Journal*, *99*(April), 17–30. https://doi.org/10.1016/j.aej.2024.04.073

Arenas-martija, A. (2025). Continuing professional development in teachers : insights for designing a formative trajectory in scientific education. *Frontiers in Education*, *21*(July), 1-21. https://doi.org/10.3389/feduc.2025.1537502

Artanti, Y., Yogyakarta, U. N., & Azhari, A. (2025). Global Trends , Gaps , and Methodological Insights : Intercultural Research in Indonesian Applied Linguistics and Language Education. *European Journal of Educational Research*, *12*(5), 38–62. https://doi.org/10.12973/eu-jer.15.1.341

Asmare, M. A. (2025). Social Sciences & Humanities Open Teachers ' experiences of continuous professional Development : Implications for policy and practice. *Social Sciences & Humanities Open*, *11*(April), 101514.1-19. https://doi.org/10.1016/j.ssaho.2025.101514

Avila-garzon, C., & Bacca-acosta, J. (2025). Curriculum , Pedagogy , and

Teaching / Learning Strategies in Data Science Education. *Education Sciences*, *15*(2), 1-30. https://doi.org/10.3390/educsci15020186

Bagus, I., & Puja, P. (2024). The mediating role of online learning motivation in the influence of service quality , social media usage , and pedagogical teaching competence of teachers on student learning satisfaction. *Cogent Social Sciences*, *10*(1), 1-30. https://doi.org/10.1080/23311886.2024.2396934

Barthakur, A. (2025). Advancing Holistic Decision- - Making Systems in Schools : Insights From Academic Research and Practical Applications. *Journal of Computer Assisted Learning*, *41*(3), 1–13. https://doi.org/10.1111/jcal.70021

Cabral, L., Pinto, R., & Gonçalves, G. (2025). AI-powered learning analytics dashboards : a systematic review of applications , techniques , and research gaps. *Discover Education*, *4*(252), 1-27. https://doi.org/https://doi.org/10.1007/s44217-025-00964-y

Elsawah, W. (2025). International Journal of Educational Research Open Exploring the effectiveness of gamification in adult education : A learner-centric qualitative case study in a dubai training context. *International Journal of Educational Research Open*, *9*(April), 100465.1-10. https://doi.org/10.1016/j.ijedro.2025.100465

Farah, A. A., Mohamed, M. A., Ali, M., Yusuf, I. A., & Abdulle, M. S. (2025). Impact of Islamic banking on economic growth : a systematic review of SCOPUS-indexed studies (2009 – 2024) Impact of Islamic banking on economic growth : a systematic review. *Cogent Economics & Finance*, *13*(1), 1-28. https://doi.org/10.1080/23322039.2025.2490819

Farisia, H., Santoso, A., & Kusumaningrum, S. R. (2025). Assessing the differentiated learning practice within islamic primary schools : challenges in the absence of technology. *Cogent Education*, *12*(1), 1-19. https://doi.org/10.1080/2331186X.2025.2563706

Gao, Y. (2025). Computers and Education : Artificial Intelligence Deep learning-based strategies for evaluating and enhancing university teaching quality. *Computers and Education: Artificial Intelligence*, *8*(December 2024), 100362.1-12. https://doi.org/10.1016/j.caeai.2025.100362

González, P. B., Reiss, M. J., & Reiss, M. J. (2025). Studies in Science Education Introducing sociopolitical approaches to science education : an integrative review of the concept of subjectivity in science curricula and continuous professional development programmes Introducing sociopolitical

approaches to. *Studies in Science Education*, *23*(2), 1–41. https://doi.org/10.1080/03057267.2025.2563997

Isnaeni, F., & Budiman, S. A. (2025). Analysis of the Readiness for Implementing Deep Learning Curriculum in Madrasah from the Perspective of Educators. *Jurnal Pendidikan Guru Madrasah Ibtidaiyah*, *8*(1), 15–30. https://doi.org/10.54069/attadrib.v8i1.841

Jamieson, J., Bramley, A., Gibson, S., Mnd, M. K., & Palermo, C. (2025). Evidence-informed propositions for a whole-of-program assessment approach. *Nutrition & Dietetics*, *82*(August), 518–536. https://doi.org/10.1111/1747-0080.70043

Karila, K., & Kupila, P. (2023). Multi - professional teamwork in Finnish early childhood education and care. *International Journal of Child Care and Education Policy*, *17*(21), 1-20. https://doi.org/10.1186/s40723-023-00124-5

Keryan, T., Uhlhorn, B., Wals, A., Jones, M., & Radinger-peer, V. (2025). Urban Forestry & Urban Greening Exploring the understanding and integration of nature-based solutions into higher education and TVET : Insights from 7 EU countries. *Urban Forestry & Urban Greening*, *114*(2), 129163.1-12. https://doi.org/10.1016/j.ufug.2025.129163

Khan, M., Khan, A., Ullah, A., Shakeel, M., & Khan, K. (2024). Heliyon Intelligent prediction modeling for flexural capacity of FRP-strengthened reinforced concrete beams using machine learning algorithms. *Heliyon*, *10*(1), e23375.1-22. https://doi.org/10.1016/j.heliyon.2023.e23375

Khan, W., Qazi, A., & Anna, R. (2025). Heliyon Microlearning beyond boundaries : A systematic review and a novel framework for improving learning outcomes. *Heliyon*, *11*(2), e41413.1-29. https://doi.org/10.1016/j.heliyon.2024.e41413

Kumar, V., & Kushwaha, B. P. (2025). A systematic literature review of virtual reality in tourism marketing using a mixed method. *Cogent Business & Management*, *12*(1), 1-26. https://doi.org/10.1080/23311975.2025.2528161

Lee, J., Alonzo, D., Beswick, K., Michael, J., Abril, V., Chew, A. W., & Zin, C. (2024). Dimensions of teachers ' data literacy : A systematic review of literature from 1990 to 2021. In *Educational Assessment, Evaluation and Accountability* (Libk. 36, Zenbakia 2). Springer Netherlands. https://doi.org/10.1007/s11092-024-09435-8

Lin, L., Zhou, D., Wang, J., & Wang, Y. (2024). A Systematic Review of Big Data Driven Education Evaluation. *SAGE Open*, *22*(19), 1–18.

https://doi.org/10.1177/21582440241242180

Maharani, N. Z., Kurniawan, S. S., & Sensuse, D. I. (2024). Motivations and Potential Solutions in Developing a Knowledge Management System for Organization at Higher Education : A Systematic Literature Review. *Journal of Information Systems Engineering and Business Intelligence*, *10*(2), 270–289. http://dx.doi.org/10.20473/jisebi.10.2.270-289

Marini, A., Hardam, R., & Marfu, A. (2025). Journal of Open Innovation : Technology , Market , and Complexity Smart education for a sustainable future : Integrating IoT and big data in sustainability-based learning. *Journal of Open Innovation: Technology, Market, and Complexity*, *11*(August), 1-12. https://doi.org/10.1016/j.joitmc.2025.100638

Masumbika, M., & Patrick, N. (2024). Discover Sustainability Enhancing environmental decision - making : a systematic review of data analytics applications in monitoring and management. *Discover Sustainability*, *5*(290), 1-21. https://doi.org/10.1007/s43621-024-00510-0

Mukred, M., Asma, U., Hawash, B., & Alsalman, H. (2024). Heliyon The adoption and use of learning analytics tools to improve decision making in higher learning institutions : An extension of technology acceptance model. *Heliyon*, *10*(4), e26315.1-19. https://doi.org/10.1016/j.heliyon.2024.e26315

Ncube, M. M., & Ngulube, P. (2025). Mapping theoretical approaches : a scoping review of data analytics in higher education. *Discover Education*, *4*(201), 1-21. https://doi.org/10.1007/s44217-025-00647-8

Nguyen, D., Boeren, E., Maitra, S., & Cabus, S. (2024). Professional Development in Education A review of the empirical research literature on PLCs for teachers in the Global South : evidence , implications , and directions. *Professional Development in Education*, *50*(1), 91–107. https://doi.org/10.1080/19415257.2023.2238728

OECD. (2019). *PISA 2018 results (Volume I): What students know and can do. OECD Publishing: Libk. I*. https://doi.org/10.1787/5f07c754-en

OECD. (2021). *21st-century readers: Developing literacy skills in a digital world. OECD Publishing*. https://doi.org/10.1787/a83d84cb-en

Rahmi, I., & Rassanjani, S. (2025). Social Sciences & Humanities Open Enhancing teacher quality in Indonesia : The impact of teacher professional development on achieving sustainable development goal 4 . c. *Social Sciences & Humanities Open*, *12*(October), 102123.1-9.

https://doi.org/10.1016/j.ssaho.2025.102123

Raitskaya, L., & Tikhonova, E. (2024). Evidence-Based Social Sciences and Practices : A Scoping Review. *JOURNAL OF LANGUAGE & EDUCATION*, *10*(2), 5–31. https://doi.org/10.17323/jle.2024.21681

Rogers, E. M., & Everett, M. (1962). *DIFFUSION OF Third Edition*.

Roshid, M. M., & Haider, M. Z. (2024). Teaching 21st-century skills in rural secondary schools: From theory to practice. *Heliyon*, *10*(9), e30769.1-19. https://doi.org/10.1016/j.heliyon.2024.e30769

Shanmugam, S. K. S., Veloo, A., & Ng, S. B. (2025). Exploring the barriers to implementing hybrid learning in rural primary schools. *Cogent Education*, *12*(1), 1-19. https://doi.org/10.1080/2331186X.2025.2569691

Smiliotopoulos, C., Kambourakis, G., & Kolias, C. (2024). Heliyon Detecting lateral movement : A systematic survey. *Heliyon*, *10*(4), e26317.1-24. https://doi.org/10.1016/j.heliyon.2024.e26317

Stufflebeam, D. L., & Coryn, C. L. S. (2007). *Evaluation Theory, Models, And Applications*.

Susanto, R., Agustina, N., & Nasution, E. S. (2025). Evaluation of Educational Management in Improving Teacher Competence to Achieve National Elementary School Education Standards. *Journal of Educational Research and Evaluation*, *9*(3), 517–529. https://doi.org/10.23887/jere.v9i3.96205

Susanto, R., & Rozali, Y. A. (2022). Analisis kompetensi dan peran coach akademik terhadap kemampuan guru dalam menerapkan strategi pengembangan kompetensi pedagogik. *Jurnal Konseling dan Pendidikan*, *10*(1), 1–11. https://doi.org/10.29210/169300

Susanto, R., Rozali, Y. A., & Agustina, N. (2019). Development of Pedagogical Competency Models for Elementary School Teachers : Pedagogical Knowledge , Reflective Ability , Emotional Intelligence and Instructional Communication Pattern. *Universal Journal of Educational Research*, *7*(10), 2124–2132. https://doi.org/10.13189/ujer.2019.071010

Tamadoni, A., & Hosseingholizadeh, R. (2024). A systematic review of key contextual challenges facing school principals : Research- informed coping solutions. *Educational Management Administration & Leadership*, *52*(1), 116–150. https://doi.org/10.1177/17411432211061439

Ugwu, O. P., Ogenyi, F. C., Alum, E. U., Eze, H. U., Basajja, M., Ugwu, J. N., Chinyere, N., Ejemot-nwadiaro, R. I., Okon, M. Ben, Ikechukwu, S., Ejim, U. D., Ugwu, O. P., Ogenyi, F. C., Alum, E. U., Hyginus, V., Eze,

U., Basajja, M., Ugwu, J. N., Ugwu, C. N., … Daniel, U. (2025). Implementing artificial intelligence and machine learning algorithms for optimized crop management : a systematic review on data- driven approach to enhancing resource use and agricultural sustainability. *Cogent Food & Agriculture*, *11*(1), 1-37. https://doi.org/10.1080/23311932.2025.2569982

Wong, F., & Ling, W. (2024). Nurturing Innovation , Transforming Education : A Longitudinal Study. *Journal Of Research, Innovation, And Strategies for Education*, *1*(1), 1–16. https://doi.org/10.70148/rise.1

Zambrano-romero, W., Rodriguez, C., Pita-valencia, J., Zambrano-romero, W. J., & Moran-tubay, J. M. (2025). Machine Learning in the Teaching Quality of University Teachers : Systematic Review of the Literature 2014 – 2024. *Information*, *16*(3), 1-28. https://doi.org/10.3390/info16030181