BERBAKTI: Jurnal Pengabdian Kepada Masyarakat
Vol. 4 No. 1, May 2026, Hal 62-71
e-ISSN 2987-033X, https://doi.org/10.30822/berbakti.v4i1.5349
Open Access: https://journal.unwira.ac.id/index.php/BERBAKTI

Interactive Classroom Training Based on Deep Learning for Mathematics Teachers at Muhammadiyah Vocational Schools in Kendal

Muhamad Aris Sunandar[1*], Zahid Abdush Shomad[2], Farah Dzil Barr[3], Nur Aliyyah Irsal[4], Nathasa Pramudita Irianti[5], Lilis Nurasiah[6], dan Fauzi Yuberta[7]
[1,2,3,4,5,6,7] Sekolah Tinggi Pertanahan Nasional, Indonesia

e-mail: Muhamadaris@stpn.ac.id[1*]

ARTICLE INFO

Article history:
Received: May 01, 2026
Revised: May 11, 2026
Accepted: May 25, 2026

Keywords: Formative Assessment; Interactive Classroom; Professional Development; Technological Pedagogical Content Knowledge; Vocational Mathematics.

ABSTRACT

This community service program aimed to strengthen the initial readiness of mathematics teachers in the Mathematics Teacher Association of Muhammadiyah Vocational Schools in Kendal Regency to design interactive classrooms based on a pedagogical deep learning approach. The program responded to teachers' need for pedagogically grounded digital integration, vocational contextual problems, formative assessment, and collaborative lesson design. The activity was conducted on 8 to 9 August 2025 at SMK Muhammadiyah 3 Weleri, Kendal, Central Java, involving 15 mathematics teachers. A product-based participatory capacity-building model, the 4R Workshop, was implemented through reorientation, design, peer review, simulation, and reflective follow-up. Data were collected using pre-test and post-test instruments, product review rubrics, observations, documentation, presentations, and written reflections. The results showed an increase in teachers' average competence score from 52.00 to 81.75, with an average improvement of 57.45% and a normalized gain of 0.62 in the medium category. Participants produced vocational mathematics learning designs containing objectives, driving questions, contextual problems, collaborative activities, digital media, formative assessment, and reflection. These findings indicate that practice-based, product-oriented, and teacher association-supported training can improve teachers' initial readiness to design interactive vocational mathematics learning. However, it has not yet measured changes in long-term classroom practice or student learning outcomes.

INTRODUCTION

Mathematics education in vocational high schools serves a strategic function by equipping students not only with computational procedures but also with reasoning, modeling, decision-making, and data interpretation skills. High-quality learning requires alignment among objectives, activities, and assessment so that students understand the meaning of concepts rather than merely repeat procedures (Biggs & Tang, 2007). In vocational mathematics, this understanding is particularly important because students need to connect mathematical concepts with measurement, production, costs, sales data, and authentic workplace problems (Rillero, 2016).

A recurring problem in mathematics classrooms is the dominance of lecturing, worked examples, and routine exercises. These strategies may support procedural problem solving, but they do not always build students' ability to transfer knowledge to new problems (Hmelo-Silver, 2004). Deep learning in this article refers to a pedagogical approach that encourages students to understand concepts, connect knowledge, engage in dialogue, reflect on their thinking processes, and apply ideas in meaningful situations (Fullan et al., 2018). This meaning differs from the use of "deep learning" to refer to a branch of artificial intelligence. Therefore, the term is used in this article to refer to a pedagogical approach (Rillero, 2016).

National curriculum policy also demands learning that is relevant, adaptive, and oriented toward students' competency development. The Regulation of the Minister of Primary and Secondary Education Number 13 of 2025 serves as a recent policy reference for curriculum adjustments in early childhood education, primary education, and secondary education. (Kementerian Pendidikan Dasar dan Menengah Republik Indonesia, 2025). Based on this policy direction, vocational mathematics teachers need to develop interactive, contextual, and responsive learning that is responsive to technological development. An interactive classroom is understood as a classroom that provides opportunities for students to ask questions, discuss, explore representations, use media, and receive formative feedback (Hattie & Timperley, 2007).

Technology integration in an interactive classroom should not be understood merely as the use of applications. The Technological Pedagogical Content Knowledge (TPACK) framework explains that teachers must integrate content knowledge, pedagogy, and technology so that digital media genuinely support learning objectives (Mishra & Koehler, 2006). Pedagogical content knowledge emphasizes the importance of pedagogical understanding of subject matter (Shulman, 1986), while technological pedagogical knowledge in mathematics and science education needs to be connected to subject-specific practice (Niess, 2005). Reviews of TPACK also show that teachers' beliefs, content characteristics, and pedagogical design influence the success of technology integration (Voogt et al., 2013). Previous AI training at SMK Muhammadiyah 3 Weleri showed that teachers were able to use ChatGPT, Microsoft Copilot, Google Gemini, Quizizz, and SlidesGo to prepare teaching modules, quizzes, visualizations, and presentations when the program combined conceptual explanation with direct demonstration (Sunandar, 2024).

Teacher professional development is central to improving learning design. Professional development programs are more effective when they focus on content, provide active learning opportunities, support collaboration, offer practice models, offer feedback, and have sufficient duration (Darling-Hammond et al., 2017). Teacher learning occurs through interaction among teachers, facilitators, materials, and the school context (Borko, 2004). Program coherence and active teacher participation are associated with changes in knowledge and practice (Desimone, 2009; Garet et al., 2001). Changes in teachers' beliefs tend to become stronger after teachers obtain evidence of success from practice (Guskey, 2002).

The Mathematics Teacher Association of Muhammadiyah Vocational Schools in Kendal Regency has a strategic role as a professional learning community. The teacher association can serve as a forum for sharing learning tools, conducting peer review, reflecting on classroom practice, and supporting implementation. Social constructivism states that knowledge develops through social interaction and mediation (Vygotsky, 1978). Teacher professional learning also needs to be linked to students' needs and evidence of learning outcomes (Timperley et al., 2007). Based on initial coordination with the partner, teachers needed examples of interactive classroom designs that not only used digital media but also connected mathematics with vocational contexts. This need is consistent with the 2024 activity report from the same school, which noted that some teachers had not yet used AI and that the use of digital technology in learning remained suboptimal (Sunandar, 2024).

The main gap this program addresses is the limited availability of training for vocational mathematics teachers that integrates deep learning, TPACK, vocational contexts, product evaluation, and teacher-association-based follow-up. Many technology training programs still focus on application use, whereas successful digital learning requires deeper pedagogical design (Lawless & Pellegrino, 2007). Previous AI training with the same partner introduced an AI-assisted module and quiz development. However, follow-up was still required to more closely connect technology use to contextual and reflective mathematics learning design (Sunandar, 2024). To respond to this need, the program offered the 4R Workshop model, consisting of conceptual reorientation, interactive vocational classroom design, peer review and simulation, and reflection with follow-up planning. The model was positioned as a product-based intervention, enabling teachers to produce learning designs that could be replicated and further developed through the teacher association.

Based on this background, the community service program aimed to improve teachers' understanding of deep learning as a pedagogical approach in mathematics education, strengthen teachers' skills in designing interactive classrooms based on vocational contexts, enhance teachers' ability to integrate digital media pedagogically, and produce interactive mathematics learning designs that can be further developed through the teacher association.

IMPLEMENTATION METHOD

This community service program used a product-based participatory capacity-building model. Capacity building was selected because the program sought to strengthen teacher competence through experience in designing, practicing, receiving feedback, and reflecting on learning designs. This principle is consistent with teacher professional development that places active practice and collaboration as core components (Darling-Hammond et al., 2017). The model also adopted a multilevel evaluation orientation that covered participant responses, knowledge and skill improvement, product quality, and follow-up planning (Kirkpatrick & Kirkpatrick, 2006).

The program was conducted on 8 to 9 August 2025 at SMK Muhammadiyah 3 Weleri, Kendal, Central Java. The participants were 15 mathematics teachers who were members of the Mathematics Teacher Association of Muhammadiyah Vocational Schools in Kendal Regency. The program was designed as a follow-up to an introductory AI-based learning training held on 19 January 2024 at SMK Muhammadiyah 3 Weleri, which also involved 15 teachers. The 2025 program expanded the focus from introducing AI tools to designing interactive mathematics classrooms based on deep learning (Sunandar, 2024). The partner was involved not only in participant coordination and venue provision, but also in identifying training needs, selecting vocational mathematics topics, reviewing preliminary learning designs, providing feedback during product presentations, and formulating teacher association-based follow-up plans. The partner needs map is presented in Table 1, and it served as the basis for selecting the intervention used in the program.

Table 1. Partner Needs Map and Program Solutions

Initial problem	Evidence of need	Program need	Program solution
Mathematics learning was still dominated by procedural instruction	Initial discussion showed that teachers needed examples of contextual problems	Learning designs based on conceptual understanding and context	Reorientation to deep learning and development of vocational problems
Digital media were not always connected to pedagogical objectives	Teachers were familiar with applications, but needed media selection strategies	TPACK-based technology integration	Practice with Canva, Quizizz, Wordwall, Google Slides, GeoGebra, and spreadsheets
Formative assessment was not yet designed systematically	Teachers needed examples of quizzes, rubrics, and reflection activities	Feedback instruments and achievement indicators	Workshop on formative assessment and product rubric development
Learning tool sustainability required a collective forum	The teacher association had a regular mathematics teacher forum	Peer review and a learning tool repository	Reflection and teacher association-based follow-up

The intervention flow was organized using the 4R Workshop model, as shown in Figure 1. The four stages guided participants through conceptual clarification, design development, peer review, simulation, and reflection. This sequence was selected to translate the needs identified in Table 1 into measurable activities, instruments, and outputs.

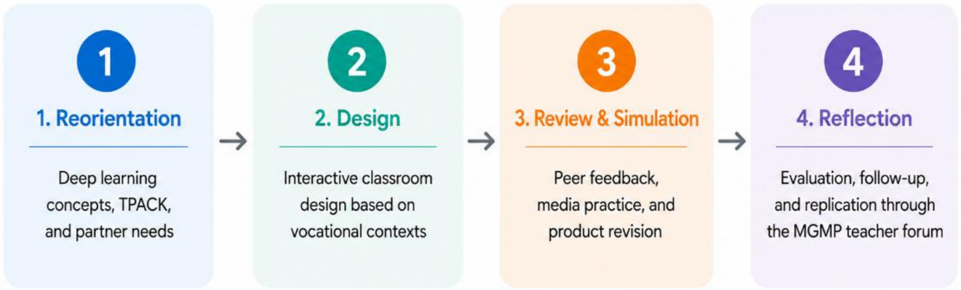

Figure 1. The 4R Workshop Model for Strengthening Interactive Classrooms Based on Deep Learning.

To support implementation and evaluation, each stage of the 4R Workshop was mapped into objectives, main activities, instruments, and outputs, as summarized in Table 2. This matrix shows how the program objectives were linked to the evidence of achievement used in the evaluation.

Table 2. Matrix of Objectives, Activities, Instruments, and Outputs

Objective	Main activity	Instrument/data	Output
Understand deep learning pedagogically.	Conceptual reorientation, example discussion, and misconception analysis	Pre-test, post-test, observation	Improved conceptual understanding
Design interactive vocational classrooms.	Workshop on learning objectives, driving questions, and contextual problems	Product rubric and presentation	Draft learning design
Integrate digital media	Practice using media for exploration, quizzes, and collaboration	Observation and TPACK rubric	Selected digital media or activity
Develop formative assessment	Preparation of quizzes, reflective questions, and simple rubrics	Product review	Formative assessment instrument
Prepare a teacher association-based sustainability.	Reflection, follow-up discussion, and peer review commitment	Written reflection	Follow-up plan

The activity sequence was then arranged into daily operational stages, as presented in Table 3. The first day focused on strengthening the conceptual framework and the foundation of learning design, while the second day was used for media practice, product review, simulation, evaluation, and reflection. Through this flow, the 4R model did not stop at conceptual training but generated learning design products that could be reviewed collaboratively.

Table 3. Operational Stages of Program Implementation

Stage	Activity	Objective	Output
Needs identification	Coordination with the teacher association, discussion of learning problems, and needs mapping.	Determine the program focus	Training needs map
Reorientation	Pre-test, strengthening of deep learning, interactive classrooms, TPACK, and formative assessment	Establish a shared conceptual framework	Participants' initial understanding

Design	Workshop on vocational mathematics learning design	Produce initial products	Draft learning tools
Review and simulation	Digital media practice, product presentation, and peer feedback	Improve learning design quality	Revised products and feedback
Reflection	Post-test, written reflection, and teacher association-based follow-up plan	Assess achievement and sustainability	Evaluation data and follow-up plan

Program evaluation used several data sources, including pre-test and post-test data, process observations, documentation, product reviews, participant presentations, and written reflections. The evaluation grid in Table 4 was used to ensure that the evaluation assessed not only conceptual mastery but also participants' ability to design learning, select technology pedagogically, and develop formative assessment. Product rubrics were necessary because design skills cannot be fully assessed through knowledge tests alone (Desimone, 2009).

Table 4. Evaluation Grid of Teacher Competence

Indicator	Measurement focus	Instrument form	Score
Understanding of deep learning concepts	Understanding of definitions, principles, and examples of deep learning	Conceptual test and discussion	0-100
Ability to design interactive classrooms	Objectives, driving questions, collaborative activities, and learning flow	Product rubric	0-100
Digital media integration	Alignment of media with content, pedagogy, and student needs	TPACK rubric and observation	0-100
Formative assessment	Quizzes, feedback, reflective questions, and success indicators	Product rubric	0-100

Scores were obtained using a 0 to 100 scale and analyzed descriptively through mean scores, percentage improvement, and normalized gain. Low, medium, and high categories followed the interpretation of learning evaluation based on normalized gain (Hake, 1998). Qualitative data from observations and reflections were analyzed using simple thematic analysis, grouping participant responses into themes of needs, achievements, constraints, and follow-up (Braun & Clarke, 2006). Participant data were reported in aggregate to protect privacy.

RESULTS AND DISCUSSION

The program was implemented according to the 4R flow in Figure 1 and the operational stages in Table 3. The first day began with an opening session, pre-test, reorientation to deep learning, discussion of interactive classrooms, and strengthening of TPACK. Participants then selected vocational mathematics topics such as statistics, trigonometry, linear equations, functions, and financial mathematics. The second day focused on digital media practice, learning design development, simulation, product presentation, post-test, and reflection.

The activity photograph in Figure 2 illustrates a training atmosphere that positioned participants as learning designers rather than merely as recipients of material. This participatory pattern is important because teacher professional learning tends to be stronger when teachers engage in active practice and receive feedback from peers (Darling-Hammond et al., 2017). The discussion, practice, and presentation activities documented also formed part of the process observation data.

Figure 2. Delivery of Material and Interactive Classroom Design Discussion.

The comparison of pre-test and post-test scores in Table 5 shows improvement across all competence indicators. The average participant score increased from 52.00 to 81.75, representing a 57.45% improvement. The average N-gain was 0.62, which was in the medium category. This result indicates strengthened initial competence and readiness; however, it should not be interpreted as evidence of long-term changes in classroom teaching practice.

Table 5. Improvement in Teacher Competence Based on Pre-test, Post-test, and N-gain

Competence indicator	Pre-test	Post-test	Improvement	N-gain	Category
Understanding of deep learning concepts	56.00	84.00	50.00%	0.64	Medium
Ability to design interactive classrooms	52.00	82.00	57.70%	0.63	Medium
Ability to integrate digital media	49.00	80.00	63.30%	0.61	Medium
Ability to develop formative assessment	51.00	81.00	58.80%	0.61	Medium
Average	52.00	81.75	57.45%	0.62	Medium

The visualization in Figure 3 clarifies the improvement pattern shown in Table 5. The digital media integration indicator showed the largest increase, consistent with the training design, which allowed participants to practice using media directly. This finding supports the view that the development of teachers' technological competence is strongly influenced by practice and by the context of use (Lawless & Pellegrino, 2007). This pattern is also consistent with previous AI training with the same partner, in which direct demonstrations and practice in developing AI-assisted modules and quizzes received 100% participant satisfaction (Sunandar, 2024). Nevertheless, these results should be read as an initial achievement because continued mentoring is still required.

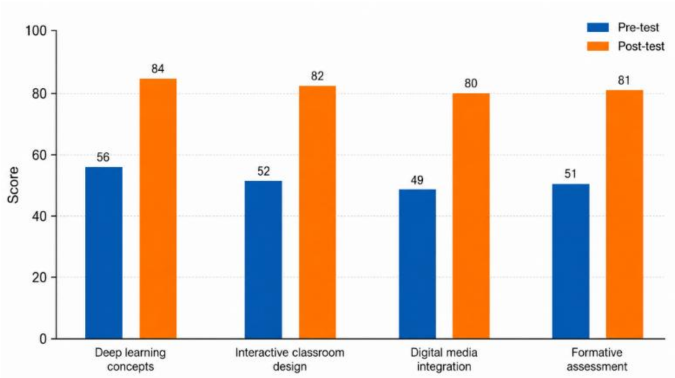

Figure 3. Comparison of Pre-test and Post-test Scores across Four Competence Indicators.

The main products generated by participants were interactive mathematics classroom designs based on deep learning. The design components included learning objectives, driving questions, vocational contextual problems, collaborative activities, digital media, formative assessment, and reflection. Several examples of participant products are summarized in Table 6, which shows teachers' efforts to connect mathematics topics with vocational fields and workplace situations.

Table 6. Examples of Participants' Interactive Classroom Design Products

Mathematics topic	Vocational context	Interactive media	Activity and assessment
Statistics	Analysis of sales and production data	Spreadsheet and Quizizz	Processing data, interpreting measures of central tendency, and a formative quiz
Trigonometry	Measuring object height or workplace slope	GeoGebra and Google Slides	Exploring trigonometric ratios, presenting strategies, and reflection
Linear equations	Simple production cost planning	Canva and a digital student worksheet	Discussing mathematical models, solving problems, and peer feedback
Financial mathematics	Calculating discounts, profit and loss, and installments	Wordwall and spreadsheet	Decision-making simulation and quick assessment

The pattern in Table 6 shows that vocational contexts helped teachers reduce the abstract impression of mathematics learning. Problems related to sales, production, measurement, and costs provided students with opportunities to interpret information, choose solution strategies, and explain their mathematical reasoning. The connection between authentic problems and problem-solving discussions supports deep learning because students learn through meaningful experiences (Hmelo-Silver, 2004).

Written reflections and final discussions revealed five main themes summarized in Table 7. These themes help explain the quantitative results in Table 5 by showing which parts of the program participants perceived as useful and which areas still require mentoring. The reflection analysis was conducted thematically so that qualitative data did not remain merely as documentation but could also explain the mechanism of competence development (Braun & Clarke, 2006).

Table 7. Participant Reflection Themes and Follow-up Plans

Reflection theme	Main finding	Program implication
Understanding of deep learning	Participants understood that deep learning is a pedagogical approach for deeper understanding.	More varied examples of classroom practice are needed.
Vocational context	Participants began to select problems close to vocational expertise programs.	The teacher association needs to develop a bank of contextual problems.
Digital media	Participants felt supported by direct media practice	Mentoring is needed so that media are selected based on learning objectives
Formative assessment	Participants began to develop quizzes and reflections, but the rubrics need strengthening.	Rubric clinics and peer review are needed.
Sustainability	Participants proposed product collection and routine teacher association discussions.	A digital repository and a periodic review schedule are needed.

The group photograph in Figure 4 shows participants and partners engaged throughout the program. This documentation was not presented as evidence of impact on student learning outcomes but rather as an indicator of partner participation and social capital for program sustainability. Collective support of this kind is important because changes in teacher practice require shared learning spaces and continuous reflection (Timperley et al., 2007).

Figure 4. Participants of the Workshop for the Mathematics Teacher Association of Muhammadiyah Vocational Schools in Kendal Regency.

The findings show that the 4R Workshop model, as designed in Figure 1, strengthened teachers' initial readiness to design interactive mathematics learning. The reorientation stage helped teachers distinguish deep learning as a pedagogical approach from mere technology use (Fullan et al., 2018). The design stage, mapped in Tables 2 and 3, provided space for teachers to translate concepts into learning products. Peer review and simulation then enabled participants to receive feedback on learning objectives, current product quality, and the next steps for improvement (Hattie & Timperley, 2007).

The greatest improvement occurred in digital media integration, as shown in Table 5 and Figure 3. This result indicates that direct practice is more readily translated into basic competence. Canva, Wordwall, Quizizz, Google Slides, GeoGebra, and spreadsheets became more meaningful when selected based on learning objectives and content characteristics. TPACK emphasizes that the quality of technology integration is determined by the relationship among mathematical content, pedagogical strategies, and technological affordances (Mishra & Koehler, 2006). TPACK also needs to be developed through subject-specific practice rather than technical mastery of applications alone (Voogt et al., 2013). Thus, this program extended the previous AI training from application introduction and media development toward a pedagogical design that was more clearly directed to TPACK, vocational contexts, and formative assessment (Sunandar, 2024).

The formative assessment indicator improved, but the evidence in Tables 4 and 7 shows that further mentoring is still needed. Participants began to prepare quick quizzes, reflective questions, and simple rubrics. However, the quality of formative assessment depends not only on the availability of instruments but also on teachers' ability to read students' thinking processes and provide actionable feedback (Hattie & Timperley, 2007). Therefore, subsequent activities should place greater emphasis on rubric clinics and the analysis of student responses.

The vocational contexts shown in Table 6 represent an important contribution of the program. Themes of production, sales, measurement, and costs helped teachers position mathematics as a tool for understanding workplace problems. Problem-based learning encourages students to learn through problem solving, discussion, and reflection on strategies (Hmelo-Silver, 2004). Such designs have the potential to increase the relevance of mathematics in vocational schools by using digital media to connect concepts to situations close to students' work experience.

The program also strengthened the teacher association's role as a professional learning community. Reflection data in Table 7 and the documentation in Figure 4 indicate that collaborative capital is needed to continue the program through vocational problem banks, peer review, and a digital repository. Professional learning with impact requires a continuous cycle of identifying needs, developing strategies, implementing them, and evaluating outcomes (Timperley et al., 2007). This recommendation is consistent with the previous AI training report, which emphasized the need for continuous training, infrastructure support, and periodic evaluation to sustain the implementation of learning technology (Sunandar, 2024). With support from the teacher association, the results of the two-day training need not stop at immediate achievement but can be further developed through routine practice and peer review.

Several limitations should be considered when interpreting the results. The number of participants was limited to 15 teachers, so the findings cannot be generalized broadly to all vocational mathematics teachers. The data were analyzed in aggregate, meaning that individual variation and inferential testing were not presented. The evaluation also focused on immediate post-training achievement and the quality of initial designs, not on classroom implementation or student learning outcomes. The two-day duration was sufficient to build initial readiness, but not to ensure sustained changes in teaching practice. Therefore, the claims in this article are limited to improvement in teachers' initial competence and readiness to design interactive mathematics learning based on deep learning.

CONCLUSION

The community service program conducted on 8 to 9 August 2025 at SMK Muhammadiyah 3 Weleri strengthened the initial readiness of mathematics teachers in the Mathematics Teacher Association of Muhammadiyah Vocational Schools in Kendal Regency to design interactive classrooms based on deep learning. The increase in average competence score from 52.00 to 81.75, with an N-gain of 0.62, shows that product-based training, media practice, peer review, and reflection helped teachers understand the principles of deep learning, select media pedagogically, and develop more contextually grounded vocational mathematics learning designs. The products developed by participants included learning objectives, driving questions, contextual problems, collaborative activities, digital media, formative assessment, and reflection. The impact of the program still needs to be examined through classroom implementation and measurement of student learning outcomes. Recommended follow-up includes regular peer review through the teacher association, development of vocational problem banks, management of a digital repository, and monitoring of learning tool use in classroom practice.

ACKNOWLEDGMENTS

The community service team expresses gratitude to the Mathematics Teacher Association of Muhammadiyah Vocational Schools in Kendal Regency, SMK Muhammadiyah 3 Weleri, as the host institution, and all teacher participants who actively took part in the workshop. Appreciation is also extended to Sekolah Tinggi Pertanahan Nasional (STPN) Yogyakarta for supporting the implementation of this community service program.

REFERENCES

Biggs, J., & Tang, C. (2007). *Teaching for quality learning at university* (3rd edn). McGraw-Hill Education.

Borko, H. (2004). Professional development and teacher learning: Mapping the terrain. *Educational Researcher*, *33*(8), 3–15. https://doi.org/10.3102/0013189X033008003

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Darling-Hammond, L., Hyler, M. E., & Gardner, M. (2017). *Effective teacher professional development*. Learning Policy Institute.

Desimone, L. M. (2009). Improving impact studies of teachers' professional development: Toward better conceptualizations and measures. *Educational Researcher*, *38*(3), 181–199. https://doi.org/10.3102/0013189X08331140

Fullan, M., Quinn, J., & McEachen, J. (2018). *Deep learning: Engage the world, change the world*. Corwin.

Garet, M. S., Porter, A. C., Desimone, L., Birman, B. F., & Yoon, K. S. (2001). What makes professional development effective? Results from a national sample of teachers. *American*

Educational Research Journal, *38*(4), 915–945. https://doi.org/10.3102/00028312038004915

Guskey, T. R. (2002). Professional development and teacher change. *Teachers and Teaching: Theory and Practice*, *8*(3–4), 381–391. https://doi.org/10.1080/135406002100000512

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, *66*(1), 64–74. https://doi.org/10.1119/1.18809

Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of Educational Research*, *77*(1), 81–112. https://doi.org/10.3102/003465430298487

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? *Educational Psychology Review*, *16*(3), 235–266. https://doi.org/10.1023/B:EDPR.0000034022.16470.f3

Kementerian Pendidikan Dasar dan Menengah Republik Indonesia. (2025). *Peraturan menteri pendidikan dasar dan menengah nomor 13 tahun 2025 tentang perubahan atas peraturan menteri pendidikan, kebudayaan, riset, dan teknologi nomor 12 tahun 2024 tentang kurikulum pada PAUD, jenjang pendidikan dasar, dan jenjang pendidikan menengah*. h

Kirkpatrick, D. L., & Kirkpatrick, J. D. (2006). *Evaluating training programs: The four levels* (3rd edn). Berrett-Koehler Publishers.

Lawless, K. A., & Pellegrino, J. W. (2007). Professional development in integrating technology into teaching and learning: Knowns, unknowns, and ways to pursue better questions and answers. *Review of Educational Research*, *77*(4), 575–614. https://doi.org/10.3102/0034654307309921

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, *108*(6), 1017–1054. https://doi.org/10.1111/j.1467-9620.2006.00684.x

Niess, M. L. (2005). Preparing teachers to teach science and mathematics with technology: Developing a technology pedagogical content knowledge. *Teaching and Teacher Education*, *21*(5), 509–523. https://doi.org/10.1016/j.tate.2005.03.006

Rillero, P. (2016). Deep conceptual learning in science and mathematics: Perspectives of teachers and administrators. *Electronic Journal of Science Education*, *20*(2), 14–31.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15*(2), 4–14. https://doi.org/10.3102/0013189X015002004

Sunandar, M. A. (2024). Pelatihan pengenalan pembelajaran berbasis AI bagi guru di SMK muhammadiyah 3 weleri. *Jurnal Inovasi Dan Terapan Pengabdian Masyarakat*, *4*(2), 111–117. https://doi.org/10.35721/jitpemas.v4i2.247

Timperley, H., Wilson, A., Barrar, H., & Fung, I. (2007). *Teacher professional learning and development: Best evidence synthesis iteration*. Ministry of Education.

Voogt, J., Fisser, P., Pareja Roblin, N., Tondeur, J., & van Braak, J. (2013). Technological pedagogical content knowledge: A review of the literature. *Journal of Computer Assisted Learning*, *29*(2), 109–121. https://doi.org/10.1111/j.1365-2729.2012.00487.x

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.