# Leveraging the Science of Learning and Development (SoLD) to Enhance Teacher Competencies

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**ABSTRACT**

Teacher competence is a key factor in achieving quality education, particularly in the context of implementing the Merdeka Curriculum in Indonesia. Recent advances in neuroscience and developmental science, compiled within the Science of Learning and Development (SoLD) framework, provide new insights into how humans learn and develop holistically, encompassing cognitive, emotional, social, and contextual dimensions. However, teachers' understanding of SoLD principles and their application in pedagogical practice remains limited, thereby hindering the optimization of learning environments that align with students' developmental potential. This research aims to analyze the benefits of SoLD principles for enhancing teacher competence through a qualitative literature review. The research methodology employs a qualitative approach utilizing library research with content analysis techniques applied to relevant literature. Findings demonstrate that teachers' understanding of brain malleability, individual developmental variability, and cognitive flexibility can fundamentally transform their pedagogical approaches. Teachers who implement SoLD principles undergo a paradigm shift from the traditional knowledge transmission model to facilitators of meaningful knowledge construction, with the capacity to create inclusive, responsive, and psychologically safe learning environments for all students.

***Keywords:*** *curriculum development, science of learning and development*, *teacher competence*

## 1. INTRODUCTION

Quality education constitutes an essential foundation for human resource development and national advancement. In this context, teachers hold an exceptionally strategic and significant role as agents of change capable of optimizing the potential of learners. Teacher competence, as a key determinant of learning success, has become a serious focus of attention in both national and international educational policies. However, despite the widely acknowledged importance of teacher competence, numerous challenges persist in its field implementation, particularly regarding comprehensive and sustainable professional development.

Recent research in neuroscience and developmental science has provided profound insights into how humans learn and develop. These findings demonstrate that learning is not merely a process of knowledge transmission, but rather a complex and dynamic process encompassing cognitive, emotional, social, and contextual dimensions (Cantor et al., 2018; Darling-Hammond et al., 2019a). Research on teacher professional development indicates that effective professional development programs must involve deep, collaborative, and sustained learning, rather than short-term training

disconnected from practical classroom contexts (Darling-Hammond et al., 2019b). Professional development programs connected to authentic classroom practice and involving ongoing reflection produce significant improvements in teachers' pedagogical competence.

Science of Learning and Development (SoLD) represents a synthesis of contemporary research that integrates knowledge from multiple disciplines, including neuroscience, psychology, anthropology, and sociology, to understand how individuals learn and develop within their environmental contexts (Lee et al., 2024; Osher et al., 2018). SoLD is a holistic approach that combines understanding of brain plasticity, learning dynamics, and individual uniqueness in the learning process (Heni, Iriani, & Ismanto, 2023). The SoLD framework is grounded in the understanding that every child possesses tremendous potential to learn and develop, and that environment, relationships, and experiences exert significant influence on this development. Darling-Hammond (2020) articulates practical implications of SoLD demonstrating that children's learning and development are influenced by dynamic interactions among environmental factors, relationships, learning opportunities, and interconnected physical, psychological, cognitive, social, and emotional processes. This framework indicates that learning is not merely a cognitive process, but rather a holistic experience encompassing emotional, social, and contextual dimensions.

SoLD research establishes conclusions on six fundamental principles. First, malleability, or brain plasticity, demonstrates that brain structure and function can change throughout life through quality experiences and relationships (Gola, Angioletti & Coco, 2022; Cantor et al., 2018). Second, integrated learning recognizes that cognitive, academic, social, and emotional aspects of development are intimately interconnected and work together to produce learning (Osher et al., 2018). Third, the presence of strong and trustworthy relationships constitutes an essential foundation for optimal learning and development (Oshima et al., 2023). Fourth, context and environment exert profoundly defining influences on development, including experiences, physical environment, culture, and social factors.

Fifth, individuality emphasizes that each individual possesses a unique developmental pathway (Rose, 2021), and no single approach can serve all learners. Sixth, meaning-making demonstrates that individuals construct understanding by reflecting on connections between new information and existing knowledge (Oshima et al., 2023). These findings hold profound implications for how teachers must develop their competence in daily learning practice.

Teacher competence is defined as an integrated ability encompassing diverse aspects that enable teachers to perform their functions effectively within learning contexts. According to Indonesian Education Standards, teacher competence comprises four primary dimensions: pedagogical competence, personal competence, social

competence, and professional competence. Pedagogical competence includes deep understanding of learners, ability to design and implement learning, and capacity to evaluate learning outcomes. Professional competence involves mastery of learning content and understanding of theories supporting learning (Bagou & Suking, 2020).

Contemporary research indicates that 21st-century teacher competence must expand to include new skills such as critical thinking, creativity, collaboration, and communication. Gümüş (2022) identifies that 21st-century teacher competence encompasses four clusters: ways of thinking (creativity, critical thinking, problem solving), working tools (information literacy, technology literacy), ways of working (communication, collaboration), and life in the world (citizenship, life and career skills). These competencies must be integrated into teachers' learning practice to prepare learners to face future challenges. Teacher professional development programs often fail to reflect contemporary understanding of how humans learn and develop. Furthermore, many professional development programs have yet to integrate understanding of neuroscience and developmental science into their design and implementation.

In the Indonesian context, research on teacher competence in curriculum development has revealed that significant gaps persist between theoretical foundations and field implementation practice. Limited research explicitly integrates the SoLD framework with teacher competence development in the Indonesian context. Most research on teacher competence development remains focused on traditional competencies limited to pedagogical and professional dimensions, without integrating deeper understanding of how learners learn based on contemporary neuroscience and developmental science research. This creates a significant gap between scientific knowledge about learning and current teacher competence development practices. Based on the preceding discussion, the research problem is: How can Science of Learning and Development be utilized to identify teacher competencies needed in developing learner-centered curriculum?

This article contributes by integrating the Science of Learning and Development (SoLD) framework as a foundation for reconstructing teacher competence within the context of curriculum development in Indonesia. The scientific novelty of this article lies in several important aspects. First, this article translates empirical findings from SoLD that have been validated through various studies in international educational contexts into a framework relevant to the Indonesian education system.

Second, this article provides understanding of how the six primary dimensions of SoLD (malleability of brain, integration of learning, relationship, context, individuality, and meaning making) can be translated into specific competencies teachers must possess in developing curricula responsive to individual learner needs. Third, this article demonstrates that SoLD-based teacher competence development not only enhances

the quality of academic learning, but also supports holistic learner development, including social, emotional, and identity dimensions.

Fourth, this article proposes the perspective that teacher competence development policy must shift from one-size-fits-all approaches toward adaptive, collaborative, and sustainable approaches, aligned with SoLD principles themselves. Thus, this article examines not only "what" competencies are needed, but also "how" teachers can develop these competencies through meaningful and contextual learning.

The perspective of educational equity also constitutes an important consideration in addressing this problem (Ainscow, 2020). Hammond (2019) and Themane's (2024) research on SoLD implementation in South African schools demonstrate that achieving meaningful educational transformation requires deeper understanding of how issues of race, ethnicity, gender, and poverty affect learning and development. Teachers must develop culturally responsive pedagogical content knowledge to effectively support all learners' learning within their zones of proximal development. Based on the problem and proposed solution approach outlined, this article aims to analyze fundamental principles of Science of Learning and Development into a teacher competence development framework. Additionally, it aims to explore effective strategies and models for teacher professional development in enhancing SoLD-based competence.

## 2. METHODOLOGY

This research employs directed qualitative content analysis, a deductive approach to examine how the Science of Learning and Development (SoLD) framework enhances teacher competence. Qualitative content analysis is a systematic approach to analyzing textual data through identification of recurring themes, patterns, and meanings within content. This method is particularly suitable for understanding how SoLD principles (brain malleability, integrated learning, relationships, context, individuality, and meaning-making) interact with teacher competency dimensions including pedagogical knowledge, professional skills, and socio-emotional capabilities (Bijker et al., 2024; Braun & Clarke, 2019). This research utilized library research examining scholarly documents (2018-2024) comprising peer-reviewed articles on Science of Learning and Development, teacher competence frameworks, and curriculum development research. Selection criteria prioritized direct relevance to SoLD principles, teacher competence development, and empirical grounding (Nicmanis, 2024).

The unit of analysis comprised themes and meanings related to teacher competencies and SoLD principles integration. Analysis followed three systematic phases: (1) Coding guide development based on predefined SoLD principles and competency dimensions with anchor examples; (2) Open coding identifying meaning units and preliminary codes, organized into subcategories through inductive abstraction; (3) Axial coding using constant comparison, linking codes to competency

dimensions and identifying emergent themes. Detailed coding manual development, constant comparison across sources, and triangulation procedures ensured credibility and transferability of findings.

## 3. RESULT AND DISCUSSION

Qualitative content analysis of literature reveals that integration of Science of Learning and Development (SoLD) principles significantly enhances the three dimensions of teacher competence: pedagogical competence, professional competence, and socio-personal competence. The first finding demonstrates a fundamental transformation in teachers' pedagogical approaches through understanding learning dynamics via the SoLD lens. Hammond (2019) identifies that teachers who comprehend learners' brains as dynamic and malleable systems implement more inclusive and responsive teaching practices. Teacher pedagogical competence encompassing understanding of learner characteristics exerts significant influence on students' critical thinking abilities. Research data demonstrate a strong correlation between teachers' understanding of developmental variability and their capacity to design effective differentiated learning.

The second finding reveals the role of multiple ways of knowing in creating holistic learning environments. Munro (2023) demonstrates that effective teachers integrate episodic, procedural, emotional, social, and self-identity knowledge in learning design. The Learning Policy Institute and Turnaround for Children affirm that when learning simultaneously integrates cognitive, social, and emotional dimensions, students achieve psychological safety that enables deeper intellectual engagement.

The third finding confirms that positive relationships between teachers and students function as essential foundations for learning. Osher et al. (2018) explain that warm, responsive, and consistent teacher-student relations biologically shape students' brain architecture through oxytocin and cortisol hormone regulation. Ruhimat et al. (2025) found in research conducted in Jakarta's remote areas that training programs emphasizing positive relationship building generated significant changes in teachers' instructional practices.

The fourth finding demonstrates strengthening of teachers' professional competence through pedagogical content knowledge enriched by SoLD understanding (Thompson & Smith, 2024). Darling-Hammond et al. (2019, 2022) identify that teachers who comprehend how brains process information, form schemas, and consolidate memory are capable of designing learning that facilitates meaningful knowledge construction. Hammond (2019) found that teachers integrating culture and cognition recognize that students' cultural mental models function as important cognitive hooks for effective learning.

The fifth finding reveals that teachers with strong metacognitive capacity and adaptive expertise are more effective in facilitating self-directed learning. Darling-Hammond et al. (2022) demonstrate that teachers explicitly modeling metacognitive strategies generate students who are more capable of planning, monitoring, and evaluating their own learning. Amilda and Jumhur (2024) found that professional development programs tailored to teachers' actual needs result in more effective implementation.

The sixth finding concerns the effectiveness of SoLD-based professional development programs. Darling-Hammond et al. (2020) prove that intensive, ongoing support directly connected to authentic classroom practice is far more effective. Professional learning communities based on SoLD facilitate teachers sharing effective practices and developing collective understanding about applying learning neurobiology within local contexts.

This research findings address the central question: How can Science of Learning and Development enhance teacher competence holistically? The emerging answer is through paradigmatic transformation in how teachers understand, design, and implement learning. SoLD integration does not merely add new knowledge, but transforms the fundamental lens through which teachers view learning.

When teachers understand that intelligence is malleable, they shift mindset from "some students can learn, some cannot" to all students can develop with appropriate support (A Howard-Jones, Jay, & Galeano, 2020). This epistemological shift is crucial because it directly affects pedagogical decisions, teacher expectations, and quality of classroom interactions. Munro's (2023) findings on multiple ways of knowing enrich understanding of complex and multimodal learning. Effective learning cannot be unimodal, but must accommodate diverse ways students process knowledge, integrating dimensions of identity, emotion, and social context.

Interpretation of positive relationships' role brings neuroscience perspective into relational learning theory. The finding that positive relations biologically shape students' brains through hormonal regulation provides strong scientific evidence for why "relationships are the primary process through which learning occurs." This is not merely a motivational slogan, but a fundamental neurological reality, transforming the framing from "relationships are a side effect of learning" to "relationships are the pedagogical foundation."

This research findings integrate SoLD with the established teacher competence framework. Findings on pedagogical content knowledge (PCK) enrich the traditional concept with neuroscience dimensions. Teachers must not only master content and how to teach it, but also understand how students' brains process the material, form mental schemas, and consolidate long-term learning. This creates more sophisticated and evidence-based PCK.

Findings on culturally responsive pedagogy integrate with teacher socio-personal competence theory. The interpretation is that cultural responsiveness is not merely a good social value, but a neurological imperative for effective learning. When teachers disregard students' cultural mental models, they lose the cognitive hooks that should facilitate learning. This transforms the framing from "culture is something that must be accommodated" to "culture is the fundamental architecture for learning."

Findings on adaptive expertise enrich the concept of teacher professional development. Effective programs are those tailored to teachers' actual context and needs, not top-down mandates. This aligns with SoLD principles themselves that adult learning requires personalization and responsiveness to context, creating coherence between what is taught about learning and how teachers themselves learn.

Transformative SoLD-based professional development programs must combine five essential elements: (1) intensive initial learning about SoLD principles; (2) collaborative learning communities with colleagues; (3) coaching and mentoring in practice implementation; (4) reflection spaces for critical examination; (5) leadership development for becoming change agents. The finding that collaborative learning produces collective understanding and sustained implementation modifies conventional wisdom about professional development that often remains individual and decontextualized. SoLD-based professional learning communities are not merely opportunities for sharing best practices, but essential mechanisms for collective sense-making about applying neuroscience principles within specific local contexts. Within the Indonesian context, these research findings are highly relevant given learner diversity and diverse learning contexts. SoLD principles can be applied across various Indonesian contexts. This opens opportunities to develop SoLD-based teacher development programs that are culturally adapted and resonate with the Merdeka Curriculum and Indonesian educational philosophy emphasizing character formation and holistic competence development.

## 4. CONCLUSION

This research addresses the central question of how Science of Learning and Development (SoLD) enhances teacher competence holistically. Integration of SoLD principles significantly enriches the three dimensions of teacher competence: pedagogical competence develops through understanding that intelligence is malleable and learning requires differentiated approaches; professional competence is enriched through pedagogical content knowledge informed by neuroscience; socio-personal competence is enhanced through understanding that positive relationships constitute the biological foundation of learning. Furthermore, this transformation achieves maximum effectiveness when teachers integrate multiple ways of knowing and develop adaptive expertise to facilitate self-directed learning. In conclusion, SoLD

is an epistemological lens that transforms how teachers think and act, creating teacher competence that is more integrated, evidence-based, and humanistic.

Based on these findings, recommendations are offered to various stakeholders. First, educational policymakers are advised to integrate SoLD in the development of national curricula and teacher competence frameworks, particularly the Merdeka Curriculum, supporting this through intensive professional development programs connected with authentic classroom practice. Second, higher education institutions and teacher development organizations are advised to develop SoLD-based programs combining conceptual learning, collaborative learning communities, coaching, reflection spaces, and leadership development, with attention to cultural adaptation and implementation across diverse Indonesian contexts. Third, teachers and educational practitioners are advised to actively develop understanding of how students learn through the SoLD lens, build professional learning communities with colleagues, and continuously reflect on and adapt pedagogical practices based on evidence. Through SoLD integration, Indonesia's educational ecosystem will become more responsive and effective in supporting meaningful learning and holistic development of learners.

## REFERENCES


Ainscow, M. (2020). Promoting inclusion and equity in education: Lessons from international experiences. *Nordic Journal of Studies in Educational Policy*, *6*(1), 7–16. https://doi.org/10.1080/20020317.2020.1729587

Amilda, & Jumhur. (2024). Teacher professional development planning at SMAN 6 Palembang. *Didaktika: Jurnal Kependidikan*, *13*(2), 1781-1787. https://doi.org/10.37640/jip.v16i2.2111

Braun, V., & Clarke, V. (2019). Reflecting on reflexive thematic analysis. *Qualitative Research in Sport, Exercise and Health*, *11*(4), 589–597. https://doi.org/10.1080/2159676X.2019.1628806

Cantor, P., Osher, D., Berg, J., Steyer, L., & Rose, T. (2018). Malleability, plasticity, and individuality: How children learn and develop in context. *Applied Developmental Science*, 23(4), 307–337. https://doi.org/10.1080/10888691.2017.1398649

Darling-Hammond, L., Hyler, M. E., Wojcikiewicz, S., & Rushing, J. (2025). Design Principles for Teacher Preparation: Enacting the Science of Learning and Development. *Learning Policy Institute*.

Darling-Hammond, L., Flook, L., Cook-Harvey, C., Barron, B., & Osher, D. (2019). Implications for educational practice of the science of learning and development. *Applied Developmental Science*, *24*(2), 97–140. https://doi.org/10.1080/10888691.2018.1537791

Darling-Hammond, L., Schachner, A. C. W., Wojcikiewicz, S. K., & Flook, L. (2022). Educating teachers to enact the science of learning and development. *Applied Developmental Science*, *28*(1), 1-21. https://doi.org/10.1080/10888691.2022.2130506

Gola, G., Angioletti, L., & Coco, M. I. (2022). The teaching brain: Beyond the science of teaching and educational neuroscience. *Frontiers in Psychology*, 13, 823832.

Gümüş, A. (2022). Twenty-first-century teacher competencies and trends in teacher training. In A. Gümüş (Ed.), *Teacher competencies in the 21st century* (pp. 249–280). Springer.

Hammond, Z. (2019). Looking at SoLD through an equity lens: Will the science of learning and development be used to advance critical pedagogy or will it be used to maintain inequity by design? *Applied Developmental Science*, *24*(2), 151–158. https://doi.org/10.1080/10888691.2019.1609733

A Howard-Jones, P., Jay, T., & Galeano, L. (2020). Professional development on the science of learning and teachers' performative thinking—a pilot study. *Mind, Brain, and Education*, *14*(3), 267-278.

Heni, A. M., Iriani, A., & Ismanto, B. (2023). The effectiveness of neuroscience to improve teacher pedagogic

competence: Systematic literature review. *JPI (Jurnal Pendidikan Indonesia)*, *12*(2), 198-209.

Learning Policy Institute & Turnaround for Children. (2021). *Design principles for schools: Putting the science of learning and development into action*. Learning Policy Institute.

Lee, C. D., Lerner, R. M., Gadsden, V. L., & Osher, D. (2024). The Science of Learning and Development: A View of the Issues. *Review of Research in Education*, *47*(1), ix-xviii. https://doi.org/10.3102/0091732X241244741 (Original work published 2023)

Baskara, A., & Sutarni, N. (2024). Kompetensi pedagogik guru SMA di Indonesia: Sebuah systematic literature review. *Didaktika: Jurnal Kependidikan*, *13*(3), 3481-3496.

Osher, D., Cantor, P., Berg, J., Steyer, L., & Rose, T. (2018). Drivers of human development: How relationships and context shape learning and development. *Applied Developmental Science*, *24*(1), 6-36. https://doi.org/10.1080/10888691.2017.1398650

Oshima, J., van Aalst, J., Mu, J., & Chan, C. K. (2023). Development of the Learning Sciences: Theories, Pedagogies, and Technologies. In *International Handbook on Education Development in the Asia-Pacific* (pp. 1277-1300). Singapore: Springer Nature Singapore.

Ruhimat, M. D. C., Rahyasih, & Shodikin. (2025). Bridging the gap: Enhancing the pedagogical competence of teachers at school in the outermost area of Jakarta. *Jurnal Ilmiah Pendidikan*, *16*(2). https://doi.org/10.37640/jip.v16i2.2111

Bagou, D. Y., & Suking, A. (2020). Analisis kompetensi profesional guru. *Jambura Journal of Educational Management*, 122-130.

Themane, M. (2024). Bringing the science of learning and development into the South African schools. *Review of Research in Education*, 47, 161–166. https://doi.org/10.3102/0091732X241226917

Thompson, S., & Smith, D. L. (2024). Does teacher professional development improve student learning? Evidence from leading educators' fellowship model. *Journal of Educational Research*, 117(5), 612–628.