International Society of the Learning Sciences

Developing and Applying a Framework for Teachers' Learning Sciences Literacy: Conceptualization, Instrument Development, and Empirical Insights from a Nationwide Survey in China

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Abstract: Understanding how teachers apply insights from the Learning Sciences is central to improving teaching quality. This study conceptualized and validated a framework for Teachers' Learning Sciences Literacy (TLSL). Based on literature synthesis and a three-round Delphi process, four dimensions were identified: Awareness, Knowledge, Skills, and Self-Application & Development. A 54-item self-assessment instrument was developed and validated through exploratory and confirmatory factor analyses with samples of 480 and 486 in-service teachers. The model showed strong reliability ($\alpha = .992$) and validity. Analyses of data from 486 teachers revealed high overall TLSL, with the highest in Skills and the lowest in Knowledge. Regression results showed that teaching experience, professional title, and Learning Sciences engagement were positively associated with TLSL, whereas demographic factors had limited effects. These findings clarify the construct of TLSL, provide a validated measurement tool, and highlight the importance of sustained professional learning in fostering teachers' Learning Sciences Literacy.

Introduction

Over the past decade, educational systems have faced rapid transformations driven by technologies like artificial intelligence and big data (Bit et al., 2024; Luckin & Cukurova, 2019). In this shifting landscape, understanding how people learn, the central focus of the Learning Sciences (LS), has become essential for improving teaching quality and supporting teacher professional development (Sawyer, 2014; OECD, 2018). However, while research in the Learning Sciences has significantly advanced our knowledge of learning mechanisms, teachers' understanding and application of these insights remain underdeveloped (Liu et al., 2025). Many teachers lack systematic awareness of how Learning Sciences principles translate into classroom practice, which constrains the impact of Learning Sciences on actual instruction.

Globally, calls for evidence-based teaching (Philpott & Poultney, 2018) and reflective professionalism (Darling-Hammond, 2017) have intensified, emphasizing that teachers should not only use pedagogical methods but also understand why they work. This awareness requires a foundational literacy in the Learning Sciences, the meta-competence integrating cognitive, technological, ethical, and reflective perspectives. Despite this theoretical importance, few frameworks have defined what constitutes Teachers' Learning Sciences Literacy or provided validated tools to measure it. While prior research on teacher literacies has explored diverse domains, including digital (Delcker et al., 2025) and assessment literacies (Pastore, 2023), the dimension concerning teachers' scientific understanding of learning remains largely underexplored.

This research aims to conceptualize, validate, and apply a comprehensive framework for TLSL. It seeks to provide both conceptual clarity and empirical evidence for understanding teachers' Learning Sciences Literacy as a foundation for professional growth by determining what TLSL should include, how it can be operationalized through a reliable instrument, and identifying its current levels and influencing factors among in-service teachers.

Theoretical framing: Conceptualizing teachers' learning sciences literacy

To conceptualize TLSL, it is essential to understand how the notion of literacy has evolved. Palincsar & Ladewski (2006) defined literacy as a set of practical skills for communication and goal achievement within sociocultural contexts. The OECD (2018) further expanded this notion, defining literacy as the ability to acquire and apply knowledge, skills, attitudes, and values through continuous learning and action. Building on this foundation, scholars introduced the concept of TLSL to describe teachers' capacity to apply and extend Learning Sciences knowledge in educational contexts. Zheng (2015) emphasized that adopting Learning Sciences perspectives enables teachers to better understand students' learning processes and improve instructional design. Ealier scholars (Liang & Li, 2020; Xia & Hu, 2021) described it as a general competence to enhance teaching, and Shang et al. (2024) further formally formalized TLSL as teachers' ability to integrate authentic learning mechanisms,.

The development of TLSL parallels the changing relationship between Learning Sciences and teaching practice (Sawyer, 2014). In the 21st century, advances in brain imaging and artificial intelligence further deepened

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understanding of human learning, encouraging teachers to combine scientific evidence with innovative pedagogy. Consequently, teachers' literacy now entails not only the knowledge and skills to apply Learning Sciences principles but also the awareness and capacity for continuous self-development in an evolving technological landscape (Zhang et al., 2022).

Drawing on the OECD literacy structure and theories of the Learning Sciences, we developed a multidimensional framework for TLSL through a three-round Delphi method involving ten national experts. The resulting structure includes four first-order dimensions:

- Learning Sciences Awareness: Teachers' attitudes and dispositions toward the Learning Sciences, emphasizing teachers' willingness to focus on Learning Sciences and apply theories in practice.
- Learning Sciences Knowledge: Teachers' understanding of Learning Sciences theories and principles, including ontological, epistemological, and methodological knowledge.
- Learning Sciences Skills: The capacity to apply Learning Sciences knowledge in educational practice, including teaching, assessment, emotional support, and technology application skills.
- Self-Application and Development: The ability to apply Learning Sciences to one's own professional growth, including metacognition, autonomous development, and research innovation.

Designing and validating the TLSL instrument

We developed a self-assessment instrument by transforming the theoretical subdimensions into 70 preliminary behavioral statements.

- Pilot Testing & EFA: Data from 480 teachers underwent item analysis and Exploratory Factor Analysis (EFA). Sixteen items were removed due to low or cross-loadings, resulting in a refined 54-item scale across 13 subdimensions.
- Validation & CFA: A new sample of 486 teachers confirmed structural validity via Confirmatory Factor Analysis (CFA), showing excellent fit indices ($\chi^2/df < 5$, RMSEA < 0.08, CFI > 0.97). The instrument demonstrated exceptionally high internal consistency (overall $\alpha = .992$), indicating strong reliability.

Results

Valid responses were collected from 486 in-service teachers across China. Teachers showed high levels of Learning Sciences Literacy across all four dimensions, with Skills scoring highest and Knowledge lowest.

To examine how TLSL varied, group comparison analyses were conducted. Technology use frequency showed the broadest influence, with significant positive differences across all TLSL dimensions. Furthermore, teachers who had participated in Learning Sciences training, research, or reading activities all demonstrated higher levels of TLSL than those without such experience, with reading experience showing the strongest effect.

A multivariate model explained a meaningful share of variance in overall TLSL. Among all predictors, teaching experience and professional title were positively associated with overall TLSL. Research participation and reading engagement also remained significant after covariate control, underscoring the role of sustained scholarly involvement. These results indicate that teachers' Learning Sciences literacy is more closely tied to accumulated professional growth and research engagement than to static demographic attributes.

Discussion and conclusion

This study conceptualized TLSL as a multidimensional construct, operationalizing it through a validated instrument. While frameworks such as the UNESCO digital literacy framework (UNESCO, 2018) emphasize technological and pedagogical skills, TLSL focuses on teachers' capacity to interpret and apply Learning Science evidence.

Analyses revealed generally high TLSL scores. Teachers demonstrated strong capacity to apply Learning Sciences principles in practice, but their theoretical understanding remained relatively limited. This imbalance suggests that teachers' practical proficiency may develop faster than theoretical comprehension of learning mechanisms. Regression analysis revealed that teaching experience and professional title were significant predictors, suggesting that TLSL grows cumulatively through professional reflection (Boud et al., 2013) and participation in communities of practice (Wenger, 1998). Furthermore, engagement in Learning Sciences activities, especially regular reading, was associated with higher TLSL levels. This aligns with Bandura's (2001) view that active engagement is critical to professional growth (Borko, 2004; Timperley, 2011).

This study established TLSL as a valid construct. The framework demonstrates strong psychometric properties, showing that while teachers' overall TLSL is high, deeper theoretical understanding needs to be strengthened. Future research may refine the scale to explore broader cultural contexts.

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Acknowledgments

Fund Project: Commissioned Research Topic of the Research Association of Learning Sciences of the Chinese Association of Higher Education – Research on the Design, Development and Application of Game-based Virtual Scientific Inquiry Learning Environments (No. 25XXKX003)