

Building Networks, Sharing Expertise

How Technology-Mediated Lesson Study Connects Rural Science Teachers

August 2026

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This material is based on work supported by the National Science Foundation under Award Nos. DRL-2101383 and DRL-2450874. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation. WestEd conducted a program evaluation from 2021 to 2026. Learn more about this work and view other profiles at <https://www.wested.org/support/evaluation-services/>.



Acknowledgments

We are grateful to the 3D-RST project team for their partnership throughout this evaluation. We thank the project leadership team: Heather Leary (Brigham Young University), Max Longhurst (Utah State University), Josh Stowers (Brigham Young University), and Laurel Harker, Project Manager. We also thank the project's research team: Michelle Hudson, Tracy Poulsen, and Clara Smith (Brigham Young University), Syahrul Amin (Texas A&M University), and Austin Moore (Utah State University).

We thank Andrew Grillo-Hill (WestEd) for his guidance and review throughout the development of this report.

Finally, we thank the rural science teachers who participated in the 3D-RST project. Their willingness to share their experiences and practice and contribute their expertise made this research possible.





Rural Teachers' Expertise and the Barriers to Sharing It

Rural science teachers bring contextual knowledge to their work that most professional learning models are not designed to recognize or use. These teachers know their students, their communities, and the local phenomena that make science instruction meaningful in place-specific ways. However, professional development frameworks built for other contexts rarely treat this knowledge as a resource, and the structural isolation that characterizes rural science teaching makes it difficult for teachers to share what they know, even with one another.

This brief examines how technology-mediated lesson study (TMLS), implemented through the Three-Dimensional Rural Science Teachers (3D-RST) project, created conditions under which rural science teachers could build professional networks, access one another's expertise, and deepen their capacity for three-dimensional (3D) science instruction. To understand what is at stake, we first describe who rural teachers are and what they bring to their work.

Rural communities in the United States are remarkably diverse, varying in remoteness; geography; and the racial, ethnic, and socioeconomic makeup of their populations. Each rural community carries a distinct history, culture, and social fabric (Brown et al., 2000; Lichter & Brown, 2011). Teachers in rural communities define rurality through their communities, geography, climate, local economy, and cultural identity rather than with population thresholds or distance from urban centers (Inouye et al., 2024).

While research on rural education has often treated rurality primarily as a source of deficits specifically related to their geographic isolation, limited resources, and teacher shortages (Burton et al., 2013), a growing body of scholarship challenges this framing. Rural communities possess distinctive assets directly relevant to K–12 STEM education, including proximity to the natural world, close social ties,



community resources, and deep local knowledge (National Academies of Sciences, Engineering, and Medicine, 2025).

The teachers who work in these communities are part of that asset base (Figure 1). Many teach multiple subjects and take on roles well beyond classroom instruction, such as coaching, administration, and other responsibilities that reflect deep investment in their schools and communities (Berry & Gravelle, 2013; Biddle & Azano, 2016; Hammer et al., 2005). Rural teachers develop close and sustained relationships with students and families (Inouye et al., 2024; Tran et al., 2020), and many bring a strong sense of camaraderie and tight social networks with colleagues, students, and community members. These aspects of their work distinguish rural teachers' professional lives from those of their urban and suburban teacher counterparts (Tran et al., 2020; Figure 2).

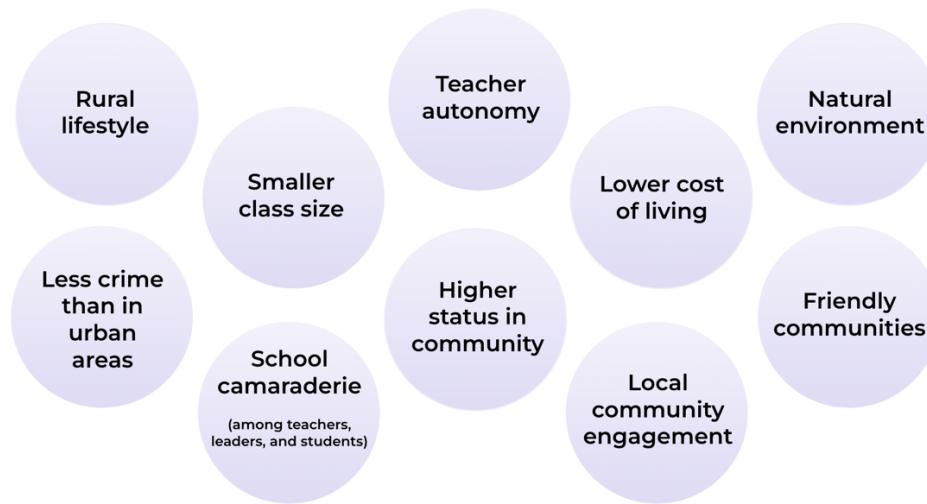
Figure 1. What Rural Teachers Carry



Note. Berry & Gravelle (2013); Biddle & Azano (2016); Inouye et al. (2024); Tran et al. (2020); Zinger et al. (2020).



Figure 2. Advantages of Teaching in Rural Areas



Note. Adapted from Tran et al. (2020).

The embeddedness in community also shapes what teachers know and how they teach. This kind of place-based knowledge does not fit neatly into professional development frameworks designed for other contexts. Drawing on deep knowledge of their students, their places, and the phenomena that matter locally, rural teachers are well positioned to ground science instruction in the authentic contexts that their communities provide. Yet this place-based expertise is not always visible to teachers themselves. Research suggests that teachers who did not grow up in the communities in which they teach may be less likely to recognize or draw on students' local sources of knowledge (Zinger et al., 2020). The experience of being raised within a community represents a form of professional knowledge that standard professional development frameworks have been slow to recognize and points to a need for professional learning that helps teachers recognize these assets within their students and communities.

Challenges associated with rural teaching are compounded by the structural conditions of rural teaching itself. Rural teachers often teach multiple classes across multiple grade levels, requiring substantive time to prepare and differentiate lessons for students. These demands are barriers to rural teachers transforming their teaching practices (Shume et al., 2022). Additional challenges



are the isolation rural teachers experience and their limited access to professional learning communities (PLCs) and peer support (Anttila & Väänänen, 2013; Lavalley, 2018), which also make it harder for teachers to surface and share the contextual knowledge they hold. The need for professional collaborative networks became more pronounced when states approved science standards based on the 3D framework of the Next Generation Science Standards (NGSS). These standards require teachers to address different content and methods of teaching and assessing science, which point to the need for more sustained professional development opportunities and collaborative peer networks (Poulsen et al., 2024).

“Rural teachers frequently remain disconnected and isolated from practitioners.”

(Poulsen et al., 2024)

Understanding why rural teachers struggle to access effective professional development requires looking at what makes professional development effective in the first place. Desimone (2009) proposes a four-step framework that traces how professional development influences teachers: Teachers participate in effective professional development, gain knowledge and skills or shift their attitudes and beliefs, adapt their instructional practices, and ultimately promote student learning. Desimone also points to contextual factors as a key mediating influence on whether each of these steps leads to the next.

Building on this emphasis, Sandholtz and Ringstaff (2016) explore these elements in greater depth to explain the contextual factors that support the sustainability of professional development. Among them is the presence of collegial support (Poulsen et al., 2024; Sandholtz & Ringstaff, 2016). Collegial support and collaboration can take a number of shapes, including one-on-one or small-group interactions, schoolwide collaboration, and exchanges with other professionals beyond the school (Darling-Hammond et al., 2017). When professional



development creates and utilizes effective collaborative structures for teachers to learn together, it can contribute positively to student achievement (Darling-Hammond et al., 2017). However, rural science teachers face structural conditions that make accessing these collaborative arrangements unusually difficult.

Rural science teachers experience professional isolation across multiple dimensions. Within their own schools, many are the only teachers of their subject or grade level, which limits opportunities for peer planning, collaborative feedback, and informal professional exchange (Zinger et al., 2020). Beyond the school, ties to other science teachers are sparse or nonexistent. In one Western state, rural science teachers reported on average fewer than one professional peer with whom to collaborate or seek support, and a quarter had no collegial connections within the bounded network at all (Poulsen et al., 2024). Even when formal collaboration structures such as organized PLCs exist at the district level, they do not remedy the professional isolation that leaves single-subject teachers in small districts without access to the content-specific exchanges they most need (Poulsen et al., 2024).

Physical distance between schools further compounds this challenge because geography is the strongest predictor of whether rural science teachers form collaborative ties (Poulsen et al., 2024). The same conditions that cut teachers off from colleagues also limit the conditions under which they can surface, share, and build on the contextual knowledge they bring to their work. Together, these conditions point to the need for models that can connect teachers who share a subject but not a building or a district.

TMLS was developed to address these needs by connecting geographically dispersed rural science teachers through structured, technology-enabled professional collaboration. The 3D-RST program, funded by the National Science Foundation (DRL-2101383 and DRL-2450874), supported rural science teachers through TMLS and examined its effects on teachers' professional networks and access to resources. To understand how those networks form and why their absence constrains teacher learning, the project draws on social network theory.





How Social Networks Shape the Flow of Professional Knowledge

Social network theory offers a conceptual framework to make the relational infrastructure (or the lack of it) that teachers may use “visible” and measurable. Borgatti and Ofem (2010) posit that relationships between people and organizations, called actors or nodes, are central to the transfer of resources and information within a network. In a teacher network, a tie might form when two teachers collaborate on a lesson or seek each other’s advice. Ties can take different forms. Expressive ties, such as friendships, tend to be durable. Instrumental ties are work oriented and are particularly effective for transferring professional knowledge, such as advice on instruction (Borgatti & Ofem, 2010). Teachers who share similar characteristics—including subject area, career stage, or grade level—are more likely to form ties, a pattern called *homophily*. Teachers who are physically close to one another are also more likely to connect, a pattern called *propinquity*.

These mechanisms, when mapped to make the relational infrastructure visible, show that a rural science teacher is often the only person in their building teaching their subject, so propinquity works against content-relevant connection rather than for it. And because same-subject colleagues are scattered across distant districts, homophily cannot compensate when those colleagues are too far away to reach. The result is a network characterized by isolates and fragmented subgroups with little exchange of information between teachers (Amin et al., 2026; Poulsen et al., 2024).

Empirical data confirm this pattern. Rural science teachers’ professional networks were found in a study by Poulsen et al. (2024) to be very sparse. In their study of teachers across one Western state, collaboration and advice networks showed extremely low density (0.008 and 0.007, respectively), with roughly 28 percent of teachers forming no collaboration ties and 30 percent forming no advice ties. On average, teachers had less than one tie to other science teachers. Where ties did



exist, they were fragmented into small, disconnected subgroups with almost no connections across regional boundaries. The absence of opportunities to collaborate with other science teachers is a barrier for teachers who are asked to teach 3D science without access to the support needed to enable their success.

How TMLS Builds Professional Networks Among Geographically Dispersed Teachers

Creating professional networks for rural science teachers requires intentional curation and exploration of novel solutions to their professional isolation. One solution is the use of a lesson study to bring teachers together to engage with one another in a sustained cycle of collaborative inquiry (Lewis & Hurd, 2011) and the use of technology to facilitate this collaboration among teachers who are otherwise separated by organizational boundaries and large distances (Poulsen et al., 2024).

TMLS builds on the collaborative foundation of lesson studies and adapts it for rural or isolated contexts by creating a technology-supported method for teachers to engage in collaboration, iterative lesson planning, peer observation, and reflective analysis (Hudson et al., 2024). TMLS is designed for use across all disciplines, but in this case it was used to support teachers in implementing 3D science learning. A growing body of research suggests that technology-mediated professional learning opportunities can expand access to more learning opportunities, support collaboration, and connect teachers in geographically dispersed areas (Inouye et al., 2023; Quinn et al., 2022; Thiele & Bogdon, 2022).

As part of the 3D-RST project, teachers engaged with TMLS throughout an academic year, beginning with an in-person, weeklong summer professional development course followed by four hybrid cycles of online synchronous and asynchronous activities and quarterly in-person meetings (Amin et al., 2026). At the beginning of the TMLS process, teachers recognized the challenges students



faced and started refining lesson materials to enhance comprehension. As the meetings continued, participating teachers updated their approach collaboratively, replacing vague readings with targeted case studies. They continually adjusted their instructions to ensure that students could engage meaningfully with each dimension. By the final meeting, the teachers confidently discussed the effectiveness of their lessons. They used an established rubric (NextGenScience, 2021) to evaluate NGSS-aligned science lessons and assess and improve differentiated supports, student assessment, and alignment with NGSS standards (Hudson et al., 2026). Figure 3 shows the steps of the TMLS process.

Figure 3. Steps of the TMLS Process



Note. Adapted from Amin et al. (2026).

A key distinguishing feature of TMLS is that it is purposefully teacher led, with practicing teachers acting as team leads and coordinators. This structure makes TMLS highly scalable and practical for rural and isolated teachers (Amin et al., 2026; Leary et al., 2025).

Evidence from the 3D-RST project shows that TMLS produced meaningful benefits for participating teachers across instructional and relational dimensions. Teachers distributed the intensive workload of building 3D lessons, developed a reusable and collaboratively designed lesson library, and deepened their understanding of 3D science instruction. They also strengthened their pedagogical



design skills and grew more confident in delivering 3D-aligned lessons (Hudson et al., 2024; Poulsen et al., 2024). Teachers described these shifts directly:

“This collaboration is the most effective collaboration I’ve ever had.”

—TMLS participant

Their discussions across the TMLS cycle reflected the trajectory of evolving from exploratory to strategic to evaluative, which is a pattern that Poulsen et al. (2024) interpret as evidence of deep professional learning and shared ownership of instructional quality. As one teacher put it,

“Just being able to watch another teacher in the classroom on video has been helpful just for a million little changes.”

—TMLS participant

Three years of longitudinal data show what those structures produced at the network level. A social network analysis of rural biology and chemistry teachers across 2022–24 found that TMLS participants became central actors in their professional networks: They were sought out by peers for collaboration, advice, and friendship at significantly higher rates than nonparticipants were (Amin et al., 2026). Collaboration networks grew between 2022 and 2023 and stabilized in 2024, reflecting that once core working relationships are established, the number of feasible connections reaches a natural limit. Advice-seeking and friendship





networks grew steadily across all 3 years as teachers progressively recognized one another's expertise and formed personal relationships that contributed to a sense of professional community (Amin et al., 2026; Moolenaar et al., 2014). Notably, TMLS participation reduced the limiting effect of geographic distance on tie formation. Participants formed long-distance connections across districts, suggesting the program generated professional relationships that would not otherwise have emerged (Amin et al., 2026).

How Trust, Friendship, and Place-Based Knowledge Sustain Network Change

Rural teachers are accustomed to working alone because of their geographic and professional isolation. This professional isolation makes it initially challenging for teachers to open up to feedback and to changes in practice that may come as a result of being part of PLCs. Accordingly, trust became an important cornerstone for TMLS. This section summarizes the description Poulsen et al. (n.d.) provided of the social processes that enabled and sustained change. The yearlong and iterative structure of TMLS created the conditions for teachers to build trust, because all teachers have to be vulnerable with recording themselves and listening to other teachers' feedback.

“It’s a different environment when you’re doing it by yourself. In the environment that we have here, I have [my team] that I can bounce ideas off ... and they’re comfortable enough to tell me, ‘You know what? That’s kind of dumb. Don’t do that.’”

—TMLS participant



Trust also came through the time added deliberately to the in-person meetings that allowed teachers to socialize, enabling deeper professional collaboration and sharing of expertise.

The trust built through TMLS did not stay bound to professional exchange. Teachers described forming friendships that they expected to last beyond the program and to go beyond knowledge exchange. In those friendships, teachers found something many rural science teachers have never had:

“I love my group. I think we’re going to stay friends. ...
It’s a big deal for me, so they are my department.”

—TMLS participant

Exchanging ideas among themselves gave them the choice to be selective and choose higher quality options now available to them, as this teacher described:

“There’s been a number of times where the other teachers bring in something that they’ve done before ... and you can take that and tie it into your class for that day. I feel like by conversing with other science teachers, you can pick and choose what you want to use.”

—TMLS participant

Once trust was established, teachers moved beyond the exchange of information and ideas to more in-depth collaboration in which teachers were encouraged to rethink their own ideas and teaching practices. As this teacher described,



“I’ve talked more with [my group of teachers in TMLS] through this past year about instruction than [I] probably had with anyone in the past 18 years.”

—TMLS participant

Furthermore, TMLS participants also expanded their own network beyond their TMLS peers. With increased confidence and skills, TMLS participants brought what they had learned back to their districts and regional networks and found that non-TMLS participants now seek them out. TMLS participants also presented at statewide conferences and shared resources with colleagues, and some nonparticipant colleagues reported benefits from those interactions.

The knowledge that moved through these networks was also tied to place. TMLS facilitators encouraged teachers to build lessons around locally relevant science phenomena, and the teachers’ own familiarity with their communities shaped what those lessons looked like. Lessons developed through the project addressed deer population dynamics and drought conditions, harmful algal blooms in local reservoirs, and mining impacts. Standard professional learning models cannot generate this kind of place-based instruction that leans in on the knowledge that the teachers, their students, and the communities bring. Through the process of TMLS, teachers are encouraged to bring this knowledge forward when designing lessons.

Implications for Professional Learning

The findings in the previous section suggest specific implications for administrators, researchers, and professional learning designers:



For Administrators

- Teacher preparation and in-service professional development programs may not adequately address the professional isolation that rural teachers face in their schools and districts. Administrators may need to coordinate with counterparts in other districts to forge professional learning experiences and professional connections.
- Administrators can support instructional improvement by creating supportive structures for connection and community around shared instructional challenges.

For Researchers

- Consider theoretical frameworks that account for contextual factors that shape behavioral change, such as the ecological model of behavior change (Stokols, 1992). This model proposes that changes in behavior are influenced by interacting factors at multiple levels: personal (attitudes, beliefs, knowledge), social (relationships, expectations, norms), and contextual (resources, time, policies).
- Develop stronger ways of measuring changes in teacher practices and connecting those practices to changes in student learning. The field still has scarce studies that link professional learning to student learning outcomes (Desimone, 2009).

For Professional Learning Designers

- Professional learning experiences should consider incorporating thoughtful relationship-building components alongside content and pedagogical knowledge goals. Collegial relationships appear to help sustain changes over time, which is an investment worth making.
- Consider whether the resources needed to accomplish a professional learning goal exist within the organization (i.e., school or district) or require networking with other organizations (i.e., across administrative boundaries).



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Suggested citation: Elsayed, R., Ringstaff, C., & Sansom, R. (2026). *Building networks, sharing expertise: How technology-mediated lesson study connects rural science teachers*. WestEd.

This material is based upon work supported by the National Science Foundation under Award Nos. DRL-2101383 and DRL-2450874. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation. WestEd conducted a program evaluation from 2021 to 2026.

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