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Review

Storying the FEW Nexus: A Framework for Cultivating Place-Based Integrated STEM Education in Rural Schools

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Abstract: When education in STEM, social science, and the humanities are disconnected from each other and from place, it is inauthentic and nonresponsive to the lived experiences of people and communities. In rural spaces, the Food–Energy–Water (FEW) Nexus, a framework for problem solving and decision-making around these central resources, is salient because of the concentration of FEW resource production and extraction present. *Storying the FEW Nexus* is an interdisciplinary pedagogical framework that is theoretically rooted in a critical pedagogy of place and socio-ecological systems. Storying the FEW Nexus brings together these two related but distinct frameworks, calling attention to the need for relevant, place-based, and rural-focused narratives within STEM instruction. Developed for K-12 learners in rural places, Storying the FEW Nexus positions STEM knowledge and skills as resources that, alongside local narratives, are vital to the sustainability and viability of communities with unique and intertwined environmental justice histories and current realities. The FEW Nexus is leveraged to support rural learners in developing sustainable solutions to local socio-ecological systems issues. In this conceptual paper, we review the literature base supporting this integrated approach, describe the framework within the context of these aims, and make suggestions for researchers and practitioners.

Keywords: rural education; place-based; STEM education; integrated STEM; Food–Energy–Water Nexus; socio-ecological systems thinking

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1. Preamble

In October 2024, the Appalachian region in the United States experienced its greatest natural disaster, one of the deadliest and most expensive Atlantic hurricanes (National Oceanic & Atmospheric Administration, 2024), as Hurricane Helene tore through in-land regions of Appalachia. While experts project the estimated damage in excess of $200 billion, the real toll was incurred by human life and the loss of community assets, such as family farms and livestock. Moreover, because of the historical poverty and underdeveloped infrastructure in the region (Peine et al., 2020) it is likely that insurance would provide little, if any, of the necessary resources for rebuilding (Bittle, 2024).

From Southwest Virginia through North Carolina and Tennessee, the aftermath of Hurricane Helene will be felt for years if not decades. The hurricane serves as a powerful example of the intersection of place, science, and engineering. Yet, back in school, many of the students who witnessed this historic flood are likely to encounter textbook examples about weather systems and economies from distant localities around the country and world. Place-based instruction offers an alternative. Place-based instruction is a pedagogical tool in which teachers can access the local community and/or geographical context to make

learning more relevant, engaging, and meaningful for students. Place-based instruction can be used as a scaffold, to increase motivation, or as the focus of instruction. In the wake of a hurricane, teachers will likely provide local examples, but with pacing guides and high stakes assessments ever beckoning, they may not have the instructional time or know-how to make deep or powerful place-based connections for students. Not only does this misalignment between standardized curricula and place-based learning represent a missed opportunity for students, it can also do unintentional harm by invalidating the real-life experiences or trauma students have experienced (J. C. Avery et al., 2020).

2. Introduction

We use this example from the rural context in which we live and work to illustrate a key point of this paper: when education in STEM, social science, and the humanities are disconnected from each other and from place, it is inauthentic and nonresponsive to the lived experiences of people and communities. Here, we aim to disrupt these divisions to illustrate the potential when STEM topics are related to a learner's sense of place through story and, simultaneously, the power of story when ecological awareness and justice (embedded in STEM understandings) is the story's throughline. Further, we situate our work specifically in rural contexts. While each community is unique, rural spaces tend to be sites of resource production and extraction with unique environmental justice stories in which the social and ecological histories and current realities are intertwined (Azano et al., 2021; Peine et al., 2020). For this work, we relied on federal definitions of rural, namely the locale codes from the National Center for Education Statistics,[1] while also recognizing that federal definitions often miss the nuance and complexity of rural places (Longhurst, 2022). Through the lens of the Food–Energy–Water (FEW) Nexus, grounded theoretically in socio-ecological systems thinking (Caniglia & Mayer, 2021) and critical pedagogies of place (Gruenewald, 2003), we developed an interdisciplinary pedagogical framework we call *Storying the FEW Nexus*. Storying the FEW Nexus aims to (a) guide teaching and learning that connects STEM to rural learners' sense of place through story, (b) develop place-based socio-ecological systems thinking, and (c) support decision-making about local FEW-Nexus resource challenges. In this paper, we review the literature base supporting this integrated approach, describe the framework within the context of these aims, and make suggestions for researchers and practitioners.

2.1. Rurality and the Needs of Learners in Rural Spaces

We focus this work in rural education where rural contexts are rarely engaged in conversations about educational standards or policies (Brenner, 2023). According to the National Rural Education Association's *Why Rural Matters 2023* report (Showalter et al., 2023), approximately 9.5 million students, or more than one in five public school students nationally, attend public schools in rural areas. The extent and quality of school-based learning opportunities should not be dependent on socioeconomic status or zip code, but they too often are. Compared to other locales, students in rural schools experience lower per pupil expenditures (Showalter et al., 2023), fewer academic resources (Azano & Callahan, 2021; Byun et al., 2015; Gagnon & Mattingly, 2015), and critical shortages in personnel (Ingersoll & Tran, 2023). These structural inequities often related to funding formulas create an uneven playing field for rural students both in and beyond their schooling experience. An "opportunity gap," like an achievement gap, is a way of understanding a systemic inequity influencing the opportunities afforded to students. Spatial inequity (Soja, 2010; Tieken, 2014)—a way of thinking about inequities specific to unique geographies (along with their economic and sociocultural contexts)—provides an opportunity for working in rural schools and communities with an equity and social justice approach. While some

challenges may exist due to geographic remoteness or otherwise seemingly intransigent barriers, schools and communities can capitalize on their assets to become sites that level the playing ground and not perpetuate inequities. This is where we situate Storying the FEW Nexus as an asset-based framework. Despite an enduring narrative that would suggest otherwise, rural places are resourced by community cultural wealth (Crumb et al., 2023), and *story* has the power to push back on deficit-based narratives. A community cultural wealth in action was notably witnessed in the aftermath of Hurricane Helene. While communities waited for government assistance, community members found ways to meet the needs of their neighbors. This involved community unity and rural ingenuity (e.g., using donkeys in some cases to deliver prescription medications when roads were flooded or washed away). By centering place in the framework, we can ensure that rural students not only have greater access to learning but that the vitality and sustainability of rural places are central to the learning.

2.2. Purpose of Integrated STEM for Rural Learners

Given the aforementioned context and needs of rural learners, we ask the question: Integrated STEM for what? To answer this question, we align our work with frameworks for STEM education that center real world challenges and contexts (environmental quality, health, natural hazards, etc.) as the driver for the integration of STEM knowledge and skills (e.g., Bybee, 2010). We intentionally center the challenges that directly impact rural learners and their communities as the focal point for integrated STEM education (NASEM, 2024). Thus, the purpose of integrated STEM education in our work becomes less about preparing future scientists and engineers, and more about how learners will engage in supporting community viability, sustainability, and environmental justice (Feinstein et al., 2013; Roth & Calabrese Barton, 2004a). Integrated STEM education that aligns with the Next Generation Science Standards (NGSS) supports learners in developing and using models and constructing explanations and designing solutions, among other practices (NRC, 2012). Accurate models and useful solutions for challenges such as environmental quality must account for the interconnectedness of social and ecological systems (Caniglia & Mayer, 2021), calling for the use of a socio-ecological systems framework. Drawing on the *Learning in Places* rhizome (Learning in Places Collaborative, 2022), we position the ability to reason about complex socio-ecological systems as a primary desired outcome of our framework for integrated STEM education. Concrete, locally relevant contexts can be powerful sites of integrated STEM learning if scaffolded intentionally (Committee on Integrated STEM Education, 2014).

2.3. FEW Nexus and FEW Nexus-Based Education

As we consider the sustainability and vitality of rural places—which includes an investigation not just in local economies and geographies but in the systems that influence a particular place–we are drawn to the FEW Nexus to anchor our model for integrated STEM education. The FEW Nexus is a framework for problem solving and decision-making around these central natural resources that are necessary for modern human civilization (Food & Agriculture Organization of the United Nations, 2014). Conceptualized as a socio-ecological system, problem-solving in the FEW Nexus must be approached from an interdisciplinary perspective, not solely relegated to the purview of scientists and engineers. The FEW Nexus has been utilized in identification and modeling of FEW systems interconnections and tradeoffs in diverse fields such as policy (Bazilian et al., 2011), planning (Brinkley et al., 2023), and crop science (Gebrai et al., 2021). Current research has also focused on identifying gaps and challenges in governance (e.g., Pahl-Wostl et al., 2021) and action (Kellner, 2023) toward sustainability across sectors. A recent call to

develop emerging leaders in addressing FEW Nexus issues included the following as central abilities: "employ systems thinking, thrive in interdisciplinary teams, communicate effectively, and engage diverse stakeholders and communities" (Wade et al., 2020, p. 1). Learners in rural communities can be these leaders by becoming stewards of place.

At the local community level, especially in rural places, many sustainable infrastructure challenges arise at the intersections of food, energy, and water systems. Emerging scholarship reveals the potential of the FEW Nexus as a way to conceptualize complex systems-based natural resources challenges so that they are accessible to teachers and students (Campbell et al., 2024; Romulo et al., 2024; Spence et al., 2021). The National Collaborative for Research on Food, Energy, and Water Education (NC-FEW, 2022) is an interdisciplinary community of educators and education researchers that is advancing scholarship on using the FEW Nexus in interdisciplinary, complex systems-based educational settings. The NC-FEW community of scholars has identified the following characteristics that should ground "design and delivery of FEW Nexus-based education":

- There is intentional integration of food, energy, and water systems through interdisciplinary educational contexts.
- Decision-making about management of natural resources, which support sustainable use and development, in a complex system is centered.
- The nexus perspective, which emphasizes connections between food, energy, and water systems, is utilized in consideration of tradeoffs in potential solutions" (para. 2).

We align Storying the FEW Nexus with this vision.

3. Literature Review and Conceptual Framework

This brief review of selected literature highlights work that informs Storying the FEW Nexus. We review existing models and guidance for science/integrated STEM, the call for responsive narratives in literacy research, and describe our theoretical and conceptual foundations.

3.1. Science and STEM Education

Within the science and integrated STEM education literature, Storying the FEW Nexus is informed by previous work in the areas of (1) efforts to connect science concepts to the real world, (2) models for STEM integration, and (3) emerging guidance on STEM education for rural learners.

A widely used framework for connecting science education with real-world issues is the socio-scientific issues (SSI) approach (e.g., Sadler et al., 2007), which we briefly describe here. In this body of work SSI are positioned as both the context for science learning and as vehicles for civic engagement/citizenship education, with an emphasis on use in the high school context (Ban & Mahmud, 2024). Competencies that have been explored in prominent SSI research are akin to literacy standards and include argumentation skills, decision-making skills, motivation, and socioscientific reasoning skills (Ban & Mahmud, 2024). Sadler et al. (2007) operationalize socioscientific reasoning as having four aspects: "recognising the inherent *complexity* of SSI, examining issues from multiple *perspectives*, appreciating that SSI are subject to ongoing *inquiry*, and exhibiting *skepticism* when presented potentially biased information" [original emphasis] (pp. 387–388). While there is potential for SSI to promote citizenship through the development of socioscientific reasoning (Sadler et al., 2007), a recent review of the top 50 most cited SSI articles reveals that the most frequent dependent variables investigated were the nature of science, argumentation, conceptual understanding, and content knowledge; those in the affective domain, such as moral, character, values, and compassion, are underrepresented as research foci (Ban & Mahmud, 2024). Zeidler et al. (2009)'s work on reflective judgement through SSI shows

that these areas can be addressed by providing opportunities for students to engage in sociomoral discourse through contested and personally relevant SSI.

Of particular interest to our work is what issues are being addressed and how they are connected to the lives of students. In the study of the top 50 most cited SSI articles (Ban & Mahmud, 2024), environment/ecology and technology/science were the most prominent subject areas in which the SSI were situated, whereas sociology and policy were the least represented. Furthermore, specific local issues (e.g., establishment of a national park) were the SSI least discussed, while broader global issues such as energy and climate change were more extensively explored in the literature. One of the studies that addressed local issues (Herman, 2018) demonstrated the efficacy of place-based SSI instruction and its impact on not only students' views of the nature of science, but also "encouraged students to be more compassionate toward specified others that are negotiating contentious environmental issues" (p. 631) and its contribution to higher levels of intent to act in pro-environmental ways. In this study, however, students experienced place-based SSI through a field trip to a distant locality, traveling from Missouri to Yellowstone. For additional guidance, we turn to work that situates science learning in the community.

We draw on Roth and Calabrese Barton's (2004b) *Rethinking Scientific Literacy* to ground our thinking about where and for whom science happens. In the opening chapter, they offer us this critique of traditional school science (from the vantage point of the early 2000s):

> Students from all different kinds of backgrounds arrive at science class and are subject to a homogeneous body of knowledge upon which they are tested at the culmination of the school year. Science is defined not by how one manages, alone or collectively, to use or produce science by way of this knowledge at home or at school, in response to a need or concern or practically toward their own or their community's future. Rather, success takes the form of a predetermined response to a cooked-up problem, an abstract set of ideals, predicated upon an imposed ideology. Success (or lack of success) in this system is a form of social control, with the consequences most real for those who sacrifice most to achieve success (to be controlled) within the system, that is, acting white or masculine, privileging the demonstration of understanding locally useless knowledge over community action. (Roth & Calabrese Barton, 2004a, p. 8)

Furthermore, Roth and Calabrese Barton (2004b) situate knowledge in the community as distributed, with scientific literacy demonstrated through the ability to locate relevant knowledge when it is needed in the context of everyday situations, from personal to community level concerns. In this context, scientific knowledge is a far cry from certain and resolved, rather it is locally constructed. Roth and Calabrese Barton envision and demonstrate through their research ways in which science education can be taken up as an act of liberation. By blurring the lines between school science and other community contexts in which youth and adults find themselves, Roth and Calabrese Barton situate science education as what happens when people work together to affect change in their community, not solely relegated to the classroom. This framing is mirrored in rural science education literature. Zimmerman and Weible (2017), for example, documented a learning experience where students' knowledge of their local watershed was built upon and connected to other local issues such as placement of natural gas wells and agrichemical usage, thus engaging a FEW Nexus perspective. In their work, Zimmerman and Weible call for more attention to developing science knowledge that can be used in action, not just that which is "inert" (2017, p. 8). Eppley (2017), used Zimmerman and Weible's study to further situate critical, place-based science education in rural schools as a vehicle for social justice.

Turning from science to STEM education literature, we maintain our emphasis on real-world issues and contexts, while expanding to incorporate the role of math and technology

as tools for problem-solving and innovation (engineering). Bybee (2010) proposed a model for STEM units that are based on contemporary issues related to heath, energy efficiency, natural resources, environmental quality, hazard mitigation, and frontiers of STEM (which he adapted from Organisation for Economic Co-operation & Development, 2006). In this model, the context of the life and work situations that involve STEM are the drivers for learning and connections are made to relevant science, technology, engineering, and math standards, reports, and frameworks. Thus, the integration of STEM subjects happens through the real-world context, with specific knowledge and practices being supported as they arise. This integration should be made explicit; knowledge in individual disciplines needs to be supported to promote use through an intentional approach (NAE & NRC, 2014). Central to our work is the rural context in which our learners are situated.

The literature base for research on rural science education is small and extremely limited for STEM education. A recent report (NASEM, 2024) provides a synthesis of current literature and, in concert with guidance from the broader science and STEM education literature, provides recommendations for how to effectively approach STEM education for rural learners. One recommendation states:

> STEM curriculum developers should take into account the assets, resources, and constraints of rural districts and schools when developing instructional materials and accompanying professional learning resources and opportunities. These materials should be designed to allow for the adaptability of instructional methods to leverage local rural funds of knowledge and take place-based approaches. (p. 11)

Centering STEM learning on meaningful phenomena and problems works well in rural schools as it does in other localities. Mountaintop removal mining in Appalachia, for example, is a well-documented "everyday disaster" (p. 222) that has catalyzed local knowledge production related to issues such as drinking water and loss of habitat that can be connected to science education (Kingsolver, 2017). Additionally, the report highlights that acknowledging the assets that rural communities have, such as small class sizes and access to natural environments, is often missing from research on rural STEM education (NASEM, 2024). L. M. Avery's (2013) concept of local rural knowledge helps describe what rural children learn from interactions with family and environment that can be leveraged in STEM education. Finally, the report emphasizes the need for approaches such as culturally relevant (Ladson-Billings, 1995), culturally responsive (Gay, 2018), and culturally sustaining (Paris & Alim, 2017) pedagogies in rural communities that have seen increases in racial, ethnic, and linguistic diversity and districts that serve Indigenous communities (NASEM, 2024).

3.2. Responsive Narratives

Storying, as a key element of our framework, is a mechanism by which rural learners can connect to place through local FEW Nexus issues. An important construct for understanding the function of story in literacy research is Bishop's (1990) famous metaphor of windows, mirrors, and sliding glass doors. Books and narratives used as part of the school-based curriculum can serve as windows, providing a view into experiences distinct from the readers. As we gaze into the world of others, story serves to foster empathy for situations with which a student might not be familiar. Mirrors, by contrast, reflect a reader's identity and experiences. When stories reflect our sense of self, they validate an identity and lived experience. And, finally, sliding glass doors are books that invite students to step into different worlds. A window for a typical high school sophomore might be *Things Fall Apart* (Achebe, 1958), a novel about the impact of colonialism in Nigeria. By reading it, students learn about the historical significance of colonization through the story of the

tragic hero, Okonkwo. By contrast, a sliding glass door might be found in the reading of *To Kill a Mockingbird* (Lee, 1960). Students can walk back in time as the protagonist, Scout, reflects on her childhood and offers a first-person account of the complex racial tensions in the segregated South. To provide students with mirrors, teachers often employ young adult novels to help students connect with contemporary representations of youth. However, rural students can struggle finding mirrors in the stories they read (Ruday et al., 2021).

Culturally relevant books can support reading comprehension for diverse readers (Christ et al., 2018) and culturally responsive teaching can increase motivation during complex tasks (Anyichie & Butler, 2023); yet, teachers may struggle finding those texts for learners in rural communities. There are several resources for teachers who want to use rural-focused literary texts in their classroom, including the Whippoorwill Awards (see Bass et al., 2025), the Literacy in Place website (Parton, 2025), and the Rural Literature Library housed at Virginia Tech's Center for Rural Education (2025). For STEM teachers, the rural community itself offers endless opportunities to build culturally relevant and place-based content for students. For example, in Virginia communities impacted by Hurricane Helene, Virginia Cooperative Extension (VCE) agents were instrumental in supporting recovery efforts for communities and the agriculture industry. As integral members of the rural communities they serve, these agents were recognized for their efforts by the 2025 Land Grant University Award from the Virginia Agribusiness Council in an emotional ceremony in February 2025. "'The emotions came from knowing that the Southwest Virginia Extension agents responded to the crisis not for recognition, but because our communities needed us,' [VCE agent Kevin] Spurlin said. 'We were there helping our clients who are also our neighbors, family, and friends. We expended so much of ourselves over the last four months'" (Barlow, 2025, para. 6). The narratives about community responses to the hurricane serve as an example of a powerful text in which rural learners could find a mirror—one that reflects who they and their communities are in this particular place.

In numerous literacy studies, scholars have found potential for students when place is partnered with the curriculum. Writers can harness voice and agency when students are given the opportunity to write about their out-of-school lives (Donovan, 2016). Those out-of-school lives can serve as springboards for place-based advocacy writing. In a study with high school students in rural Nebraska, students wrote about local topics that had impacted their lives, such as the decline of family farms and closing of a local factory (Brooke, 2012). Brooke's study showcased how local issues often held global significance, noting, "local reality is almost always shaped by much more widespread cultural, natural, and economic forces" (p. 164). Ruday and Azano (2019) found that students were able to identify those local issues to write argumentative essays in acts of social activism. Not only can place engage students with their locale, used as a pedagogical tool, place can increase comprehension and motivation while engendering stewardship. For the FEW Nexus, this means deeply anchoring content to the context in which it is learned.

3.3. Theoretical and Conceptual Foundations

Storying the FEW Nexus is grounded in theories that serve to honor rural people and places while supporting learners' ability to reason about local FEW Nexus issues. We use these theories to describe what is supported by learning experiences grounded in our framework. This conceptual framework is comprised by tenets of a critical pedagogy of place, rural literacies, rural cultural wealth, and complex socio-ecological systems thinking.

3.3.1. Critical Pedagogy of Place

When I Heard the Learn'd Astronomer by Walt Whitman

When I heard the learn'd astronomer,

When the proofs, the figures, were ranged in columns before me,
When I was shown the charts and diagrams, to add, divide, and measure them,
When I sitting heard the astronomer where he lectured with much applause in the lecture-room,
How soon unaccountable I became tired and sick,
Till rising and gliding out I wander'd off by myself,
In the mystical moist night-air, and from time to time,
Look'd up in perfect silence at the stars.

In Whitman's 1865 collection, *Leaves of Grass*, he poetically described a truth about education that John Dewey would detail some 50 years later: learning should be connected to life experience. Learners too often feel like the student in Whitman's poem, listening to lectures about the natural world while growing bored and disinterested in the content when the alternative waits just beyond the school walls.

The natural world, along with the events and histories in our local communities, creates countless opportunities for curricular connections. Bass and Azano (2024) found that an explicit study of place through the reading and writing of memoirs offered rural students ways to think critically about their own sense of belonging in rural places. In defining a critical pedagogy of place, Gruenewald (2003) pushed for a more complex use of place as a pedagogical tool. Rather than using place solely to anchor learning, as it is used in traditional place-based approaches, a critical pedagogy of place should ask questions about the power of place: Who came here? Who was harmed? Whose stories are left untold?

3.3.2. Rural Literacies

Literacy goes far beyond the ability to read and write, and literacy skills develop both inside and outside of school. Rural education scholars (e.g., Donehower et al., 2007; Edmonson, 2003) have conceptualized rural literacies as a way of understanding how identities, language, and ways of being are part of a complex network in rural communities (Bass & Azano, 2024). Understanding literacies as social constructs, rural literacies serve to foster cultural sustainability. Teachers can engage with the local contexts to forge complex connections between the curriculum and the local community (R. Waller & Barrentine, 2015).

Contextualizing rural literacies for Storying the FEW Nexus, we draw on scholars who have taken up local and place-based knowledge as funds for science learning in rural spaces. The concept of local rural knowledge (L. M. Avery, 2013; L. M. Avery & Kassam, 2011) is particularly salient in that it situates the local context (including family, community, and the natural environment) as a rich source of science learning. D. Walker (2011), in reflecting on the science literacy acquired from caregivers in her local community, explained that "doing science was decoding everyday life for survival" (p. 233). Similarly, Morales (2019) identified the experiences of youth in rural agrarian settings as scientific funds of knowledge. Further, connecting to language, L. M. Avery and Hains (2017) elevated oral traditions and sayings grounded in "ecological habitats" (p. 129) as crucial sources of knowledge for science learning in service of solving complex social-ecological systems problems.

3.3.3. Rural Cultural Wealth

To situate rural communities themselves as assets for Storying the FEW Nexus, we draw on the existing framework of rural cultural wealth (Crumb et al., 2023). A community cultural wealth (Yosso, 2005) identifies social capital (i.e., aspirational, familial, linguistic, resistant, and navigational) as strengths for historically minoritized communities. Rural cultural wealth (Crumb et al., 2023) builds upon these assets by articulating specific types of assets in rural communities. Rural resourcefulness is described as the rural residents' ability

to overcome socio-contextual adversities, such as food and housing challenges, that threaten wellbeing. Rural ingenuity speaks to the inventiveness of rural people, pointing to a strong tradition of creative problem-solving. Rural familism is characterized by intergenerational support and living in communities of care. And, finally, rural community unity refers to the collective strengths, particularly as rural neighbors organize to support one another through times of crisis, as recently seen in the aftermath of Hurricane Helene.

3.3.4. Socio-Ecological Systems Thinking

Socio-ecological systems is an interdisciplinary area of scholarship, grounded in diverse fields such as environmental sociology, ecology, economics, psychology, and agriculture (Caniglia & Mayer, 2021). Central to this field is the understanding that humans and nature are coupled, and understanding the interactions between human societies and ecosystems is the primary goal of this framing (Caniglia & Mayer, 2021). The FEW Nexus, as a socio-ecological system, has been utilized by researchers and policymakers for over a decade, leading to a more robust understanding of the complex dynamics at play while prompting more questions about environmental and livelihood considerations (Simpson & Jewitt, 2019). While the role of science in understanding processes impacting availability in these resource sectors and the role of engineering in production/extraction, transportation, and other technologies is readily apparent, the role of the social sciences in the FEW Nexus problem space cannot be ignored. The social component of socio-ecological systems has been theorized by scholars in natural resource governance (Valve, 2018), for example, and efforts to critically examine the varying epistemological positions that inform our understanding of these types of systems reveal the central role of power in how they function (Cote & Nightingale, 2012). Not surprisingly, the mental models people have regarding particular socio-ecological systems are complex and highly varied (van den Broek et al., 2023). Whatever the entry point into reasoning about socio-ecological systems, systems thinking is the primary tool.

Broadly speaking, systems thinking (as conceptualized by Meadows, 2008) allows people to interrogate the problem space and potential solutions by identifying elements, interconnections among those elements, and predicting the behavior of the system over time. Complex systems, however, require systems thinking that includes seeking hidden dimensions, identifying complex interdependencies, anticipating surprising outcomes, and engaging multiple perspectives (Meadows, 2008). Researchers in the learning sciences have argued for several decades that complex systems thinking, while challenging, can (and should) be developed in K-12 settings (Jacobson & Wilensky, 2006). While there is a robust foundation of research with computational simulations that reveals promise for supporting student complex systems thinking, there is also potential for drawing on everyday experience to build conceptual understanding of complex systems phenomena (Jacobson & Wilensky, 2006). It is through this everyday experience that we return to socio-ecological systems.

Within Storying the FEW Nexus, we aim to support learners engaging in complex socio-ecological systems thinking, as conceptualized by the (Learning in Places Collaborative, 2022). The *Learning in Places Rhizome* (Learning in Places Collaborative, 2025) for field-based science learning is grounded in a wide range of research, much of which is based in Indigenous knowledge systems (e.g., Cajete, 2000), such as human-nature relations (e.g., Bruce et al., 2023), complex socio-ecological reasoning (Pugh et al., 2019), and sense-making through "walking, reading, and storying land" (Marin & Bang, 2018, p. 89). For learners, reasoning about complex socio-ecological systems can be supported through five dimensions that offer lenses to understand diversity of living beings; connections between living and non-living things; significance of place; consideration for scale (i.e., local and

global); and ethical deliberation and decision-making (Learning in Places Collaborative, 2022). We draw on this work to frame complex socio-ecological systems thinking for Storying the FEW Nexus because of the emphasis on place and historicity, the robust theoretical grounding, and the applicability to the design of educational experience for learners of all ages.

In this review, we brought together disparate areas of scholarship to inform Storying the FEW Nexus. In our interdisciplinary framework, we emphasize common threads that call for connection to place, real-world issues of local relevance, and learner sensemaking about those issues. Through anchoring STEM content and skill development in the community, learners can leverage rural literacies as they engage in socio-ecological systems thinking about the FEW Nexus.

4. Design Features of the Storying the FEW Nexus Framework

Thus far, we have described the motivation for and literature base that informed the development of the Storying the FEW Nexus framework. Here, we draw on that work to describe the design features of the framework. Given the vast landscape of integrated STEM education, it is important that any initiative clearly and fully describe the salient features of the design. The NAE and NRC (2014) recommend the use of their descriptive framework to accomplish this, emphasizing the value of a common vocabulary. The framework includes four features that are described separately but are interdependent in practice: goals, outcomes, nature and scope of integration, and implementation. We follow this guidance to describe the features of Storying the FEW Nexus.

Goals are "statements of what the developer of the particular educational intervention hopes to accomplish" (NAE & NRC, 2014, p. 33), for example, STEM literacy, interest and engagement, and workforce readiness. The goals of Storying the FEW Nexus are ultimately in service of supporting sustainability and viability of rural communities. For learners engaged in experiences grounded in Storying the FEW Nexus, we aim to develop socio-ecological systems thinking skills (Learning in Places Collaborative, 2022), make the FEW Nexus place-based and relevant as informed by the context in which students are learning, and develop the ability to use STEM knowledge and skills to explain and address local FEW Nexus related challenges (Campbell et al., 2024; Roth & Calabrese Barton, 2004b).

Outcomes are what is measurable in relation to the goals, for example, learning and achievement, STEM-related employment, and development of STEM identity (NAE & NRC, 2014). Identifying measurable outcomes for Storying the FEW Nexus is an area for further development as the framework is used and refined in practice. We anticipate potential for learning outcomes aligned with NGSS (NRC, 2012) and the National Career Clusters Framework (Advance CTE, 2025; https://careertech.org/career-clusters/, accessed on 11 June 2025), development of STEM identity (e.g., Lakin et al., 2021), and outcomes related to citizenship and community engagement (Sadler et al., 2007).

The **nature and scope of integration** includes three elements: "type of STEM connections, disciplinary emphasis, and duration, size, and complexity of initiative" (NAE & NRC, 2014, p. 41). The nature of integration for Storying the FEW Nexus emphasizes real-world FEW Nexus challenges as the focal point for STEM connections (Campbell et al., 2024) and the driver for the integration of STEM knowledge and skills (Bybee, 2010) as articulated in the Next Generation Science Standards (NRC, 2012). Through interdisciplinary learning environments, learners will consider tradeoffs in management of local food, energy, and water systems with an aim of supporting sustainable development (NC-FEW, 2022). Through engaging with stories of real FEW Nexus issues in their own communities, learners will be supported in learning science concepts to help construct explanations for relevant scientific phenomena, such as was demonstrated in Zimmerman and Weible's (2017) watershed

study. Learners will use engineering design processes to develop and test potential solutions, and use math and technology as tools in both of these endeavors. We envision educators and designers choosing the disciplinary emphasis that best aligns with their needs and context, while maintaining an integrated STEM approach by centering scientific knowledge and development of solutions as they relate to local FEW Nexus challenges. The scope of a learning experience grounded in Storying the FEW Nexus is flexible in detail, however complex socio-ecological systems thinking, connection to community and place, and opportunities to reason about local FEW Nexus issues require prolonged engagement.

Implementation focuses on "instructional design, educator supports, and adjustments to the learning environment" (NAE & NRC, 2014, p. 43). For Storying the FEW Nexus, the aim of any implementation is to anchor STEM learning to place with local FEW Nexus related narratives for relevance and connection. This can be accomplished through several approaches, and we encourage flexibility in the design of learning experiences. Here we describe three practices that have been used successfully in other contexts that we believe have the most promise for Storying the FEW Nexus: an SSI approach, case studies, and community asset mapping. These practices can be implemented in a wide range of formal and non-formal learning settings, from 4-H clubs to science and Career and Technical Education classrooms.

4.1. Socioscientific Issues Approach

A socioscientific issues approach is well supported by decades of research on effective implementation (Ban & Mahmud, 2024), making it a promising practice for developing educational experiences grounded in Storying the FEW Nexus. Sadler (2011) synthesized several different models to derive a framework for design and implementation of SSI in a range of educational contexts. Essential design elements in Sadler's framework include using a compelling issue, i.e., a local narrative about a FEW Nexus challenge (Campbell et al., 2024), to focus instruction and providing scaffolding for higher-order tools, i.e., the five dimensions for socio-ecological systems thinking (Learning in Places Collaborative, 2022). In Sadler's (2011) framework, essential learning experiences include engaging with both the scientific concepts and social dimensions related to the issue, aligning well with FEW Nexus-based education's focus on sustainable management of natural resources which requires decision-making about use and development (NC-FEW, 2022). Sadler's framework also provides guidance for the classroom environment and teacher attributes, making it a comprehensive and useful tool to guide development of SSI learning experiences. Educators and designers can use this as a starting point, layering in additional STEM knowledge and skills (e.g., engineering design in understanding proposed solutions) and centering local rural knowledge (L. M. Avery, 2013) in identifying and engaging with the FEW Nexus related issue.

4.2. Case Studies

We propose that a case study approach is a promising practice to support educators in cultivating critical place-based pedagogies (Gruenewald, 2003). As a popular approach with long-established guidance for educators (e.g., Davis, 1993), educators can connect to local professionals (Lakin et al., 2021) and leverage local rural knowledge (L. M. Avery, 2013) to develop case studies that examine narratives about how local industries, businesses, and communities interact with the FEW Nexus and ask students to utilize socio-ecological systems thinking and STEM knowledge and skills in order to address problems within the case study. These cases can explore how place influences our understanding of the world. Storying the FEW Nexus case studies can act as a mirror, window, or eventually even sliding glass door, into the learners' lived-experiences (Bishop, 1990). Through that

bridge, learners can celebrate themselves within the rural context while addressing issues that their communities may face.

4.3. Community Asset Mapping

Asset mapping is a strategy for rural educators to develop an inventory of resources within a community from an assets-based approach, focusing on the stories, organizations, and communal spaces. To begin mapping a community, educators can conduct a rural community walk (Azano et al., 2021) to explore, document, reflect, and respond to the FEW resources in the rural community. Teachers can brainstorm with each other and their students about places to visit and do online research before launching the activity. Explore the place with a drive to parts of the community with which you are less familiar, or visit familiar haunts with the perspective of a newcomer. What stands out? What stories are the places telling? Then, actually take a walk in the community. Take note of the organizations and businesses in the community, talk to shop owners and neighbors. What are the pressing FEW Nexus related issues, the local histories, and the narratives most relevant to your instruction? What socio-ecological systems dimensions are present? How might these local narratives serve to story the FEW Nexus? Community asset mapping can be used as a Storying the FEW Nexus learning experience in itself, or as a tool for educators to identify FEW Nexus related topics that can be the focus of a case study or SSI-based instruction.

5. Next Steps

In this paper, we have presented our current thinking about Storying the FEW Nexus, including the need for a novel STEM framework that is responsive to the lived experiences of learners in rural places, the literature base that we drew from in developing the framework, and the design elements of the framework itself. This is just the beginning. Here, we make suggestions for research and practice that can guide future work for those who are intrigued by the ideas we have put forth.

5.1. Recommendations for Research

Initially, we recommend that interested scholars in fields that connect to Storying the FEW Nexus take up the task of deepening the review of the literature base in each of the areas to further refine the framework. Scholars in fields such as rural education, science and integrated STEM education, environmental education, agricultural education, and many more can contribute to Storying the FEW Nexus by adding their expertise and collaborating to strengthen existing and identify new linkages across fields. Additionally, existing work in related fields can be used to further theorize and operationalize potential outcomes for learners, leading to development of instruments and protocols that can be used in research studies. We envision potential for qualitative, quantitative, and mixed methods approaches in this work.

Ultimately, research to build an evidence base for the efficacy of Storying the FEW Nexus is needed so that the research community can make recommendations and provide guidance for instructional designers and educators to use in practice. Because of the rich potential of this interdisciplinary framework to be used in diverse educational settings, we recommend an educational design research approach (e.g., Collins et al., 2004) to test the framework in real-world settings and identify key supports for learners and educators. Research could compare our proposed practices for implementation, identifying what is most supportive of the desired outcomes. Within these efforts, we encourage researchers to provide a rich description of the context in which the framework is used so that researchers and educators in diverse fields can learn more about good practice and what works, especially in underserved rural communities.

5.2. Recommendations for Practice

While Storying the FEW Nexus is novel in how we have integrated several areas of scholarship in education, each of these is well-established in its own right. Because each of the lines of inquiry that we bring together have shown the efficacy of their approaches, we posit that Storying the FEW Nexus already has significant potential for being put into practice. We encourage educators to use the framework put forth here to consider changes in their own practice that could align with elements of Storying the FEW Nexus. Educators can find their own entry points to the work and use the framework to initiate collaboration across content areas. Educators can collaborate with their learners to experiment with the framework, using their own rural context and local narratives to discover what Storying the FEW Nexus looks like for them. We recommend using the goals, outcomes, and promising practices articulated in this paper as a starting point for design of learning experiences that center place, following a backward design approach (Wiggins & McTighe, 2005). Most importantly, educators should document their experiences using Storying the FEW Nexus in practice, sharing successes and challenges with colleagues and the broader community. It is through learning and experimenting together that researchers and practitioners will ultimately understand the true impact of this framework.

6. Conclusions

In this paper, we reviewed the motivation, context, and literature basis for a new interdisciplinary pedagogical framework called Storying the FEW Nexus. Responding to calls for K-12 STEM teaching and learning to be responsive to the needs of learners in rural spaces through a rural community cultural wealth lens (Crumb et al., 2023), we framed the purpose of integrated STEM education as preparing learners to engage in socio-ecological systems thinking to support local decision-making about sustainable resource management. We argued that food, energy, and water, as interconnected and vital resource management systems, are particularly salient in rural communities, providing a rich source of local narratives and local rural knowledge that can drive place-based learning experiences. To situate Storying the FEW Nexus, we brought together several strands of science and STEM education research: the socio-scientific issues approach (e.g., Sadler, 2011), scientific literacy as situated in the community (Roth & Calabrese Barton, 2004b), integrated STEM education driven by real-world contexts (Bybee, 2010), and rural science education (NASEM, 2024). As an interdisciplinary framework, we also drew on literacy research in responsive narratives (e.g., Bishop, 1990) to articulate the power of storying as a way for rural learners to connect to place. Further, as a pedagogical framework, we grounded Storying the FEW Nexus theoretically and conceptually in critical pedagogy of place (Gruenewald, 2003), rural literacies (Bass & Azano, 2024), rural cultural wealth (Crumb et al., 2023), and socio-ecological systems thinking (Learning in Places Collaborative, 2022). Building on this foundation, we presented design features for Storying the FEW Nexus and proposed next steps for researchers and practitioners to engage with the framework.

In closing, we return to our opening vignette about historic flooding in the Appalachian region from Hurricane Helene. As time passes and curriculum is updated, students around the country may encounter this example in their textbooks. They would likely learn about the meteorological processes and mechanisms that cause inland flooding from hurricanes if these events become more frequent. They might even be presented with facts and figures about the number of deaths, the impacts on infrastructure, and the financial costs of rebuilding. As a powerful example of how agricultural production, water quality and energy transmission can be severely impaired by a single flooding event, Hurricane Helene has significant potential for an illustrative FEW Nexus case study. Presented as an SSI, learners can practice socio-ecological systems thinking as they consider who and

what was impacted, the science that helps explain observed phenomena, and consideration of tradeoffs in proposing solutions for rebuilding and preparing for future events.

But the full story includes what the people impacted by the flooding did next. They came together to help neighbors near and far. They are learning to live with a new normal and rebuilding not just infrastructure, but community ties and local history; the local history now has a new chapter, and the community holds new scientific literacies. Moving forward, people will generate new ways of living in their rural landscapes that are forever changed. These stories of resilience that likely share common threads but are unique to each community demonstrate the community cultural wealth that rural places have (Crumb et al., 2023) and they will live on to serve as an inspiration for generations to come. These stories matter and serve as powerful opportunities "for pushing back on the narrative that rural students are somehow 'less than' simply due to geographic location" (Bass & Azano, 2024, p. 4). Designing FEW Nexus learning experiences that center stories from the communities where rural learners live is responsive to their needs and can avoid the harm that may come from not addressing the real-life experiences of those who were directly impacted (J. C. Avery et al., 2020). It is through learning experiences aligned with Storying the FEW Nexus that future learners in these communities can encounter them in meaningful and powerful ways.

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Abbreviations

The following abbreviations are used in this manuscript:

STEM	Science, Technology, Engineering, and Math
FEW	Food–Energy–Water

Note

[1] See https://nces.ed.gov/programs/edge/Geographic/LocaleBoundaries, accessed on 3 April 2025.

References

Achebe, C. (1958). *Things fall apart*. Heinemann.

Advance CTE. (2025). *The national career clusters framework*. Available online: https://careertech.org/career-clusters (accessed on 11 June 2025).

Anyichie, A. C., & Butler, D. L. (2023). Examining culturally diverse learners' motivation and engagement processes as situated in the context of a complex task. *Frontiers in Education*, *8*, 1041946. [CrossRef]

Avery, J. C., Morris, H., Galvin, E., Misso, M., Savaglio, M., & Skouteris, H. (2020). Systematic review of school-wide trauma-informed approaches. *Journal of Child & Adolescent Trauma*, *14*(3), 381–397. [CrossRef]

Avery, L. M. (2013). Rural science education: Valuing local knowledge. *Theory into Practice*, *52*(1), 28–35. [CrossRef]

Avery, L. M., & Hains, B. J. (2017). Oral traditions: A contextual framework for complex science concepts—Laying the foundation for a paradigm of promise in rural science education. *Cultural Studies of Science Education*, *12*(1), 129–166. [CrossRef]

Avery, L. M., & Kassam, K.-A. (2011). "Phronesis": Children's local rural knowledge of science and engineering. *Journal of Research in Rural Education*, *26*(2), 1–18.

Azano, A. P., Brenner, D., Downey, J., Eppley, K., & Schulte, A. (2021). *Teaching in rural places: Thriving in classrooms, schools, and communities*. Routledge.

Azano, A. P., & Callahan, C. M. (Eds.). (2021). *Gifted education in rural schools: Developing place-based interventions*. Routledge.

Ban, S., & Mahmud, S. N. D. (2024). A systematic review of the top-50 most-cited articles on socio-scientific issues in K-12 education. *Eurasia Journal of Mathematics, Science & Technology Education*, *20*(4), em2425. [CrossRef]

Barlow, M. (2025, February 25). Virginia cooperative extension agents honored for hurricane helene response. *VT News*. Available online: https://news.vt.edu/articles/2025/02/cals-vce-hurricane-award.html (accessed on 14 May 2025).

Bass, E. L., & Azano, A. P. (2024). *Reading and writing place: Connecting rural schools and communities*. Lexington Books.

Bass, E. L., Young, M. J., Hoffman, A., Yahn, J., Roe, M., Brenner, D., & Parton, C. (2025). The 2024 Whippoorwill award: Gathering stories of indigeneity, connection, and belonging. *The Rural Educator*, *46*(1), 4–9. [CrossRef]

Bazilian, M., Rogner, H., Howells, M., Hermann, S., Arent, D., Gielen, D., Steduto, P., Mueller, A., Komor, P., Tol, R. S. J., & Yumkella, K. K. (2011). Considering the energy, water and food nexus: Towards an integrated modelling approach. *Energy Policy*, *39*(12), 7896–7906. [CrossRef]

Bishop, R. S. (1990). Mirrors, windows, and sliding glass doors. *Perspectives: Choosing and Using Books for the Classroom*, *6*(3), ix–xi.

Bittle, J. (2024, March 29). Hurricane Helene's flood damage cost could exceed $10 billion, insurance expert says. *Grist*. Available online: https://grist.org/extreme-weather/hurricane-helene-flood-damage-cost-insurance/ (accessed on 31 March 2025).

Brenner, D. (2023). Rural critical policy analysis: A framework for examining policy through a rural lens. *The Rural Educator*, *44*(1), 71–73. [CrossRef]

Brinkley, C., Raj, S., & Raja, S. (2023). Planning for FEWsheds: The role of planning in integrating and strengthening food, energy and water systems. *Journal of Planning Literature*, *38*(1), 33–58. [CrossRef]

Brooke, R. (2012). Voices of young citizens: Rural citizenship, schools, and public policy. In K. Donehower, C. Hogg, & E. E. Schell (Eds.), *Reclaiming the rural: Essays on literacy, rhetoric, and pedagogy* (pp. 161–172). Southern Illinois Press.

Bruce, F., Bang, M., Lees, A., McDaid, N., Peters, F., & Bushnell, J. (2023). Indigenous water pedagogies: Cultivating relations through the reading of water. *Occasional Paper Series (Bank Street College of Education)*, *2023*(49), 2. [CrossRef]

Bybee, R. W. (2010). Advancing STEM education: A 2020 vision. *Technology and Engineering Teacher*, *70*(1), 30–35.

Byun, S. Y., Irvin, M. J., & Meece, J. L. (2015). Rural–nonrural differences in college attendance patterns. *Peabody Journal of Education*, *90*(2), 263–279. [CrossRef]

Cajete, G. (2000). *Native science: Natural laws of interdependence*. Clear Light Publishers.

Campbell, T., Burrell, S., Fick, S. J., Herrick, I., McGowan, V. C., Fazio, X., & Lombardi, D. (2024). Practice Brief 96: Understanding how food, energy, and water decisions affect the thriving of local, regional, and global systems. *STEM Teaching Tools*. Available online: https://stemteachingtools.org/brief/96 (accessed on 10 March 2025).

Caniglia, B. S., & Mayer, B. (2021). Socio-ecological systems. In B. S. Caniglia, A. Jorgenson, S. A. Malin, L. Peek, D. N. Pellow, & X. Huang (Eds.), *Handbook of environmental sociology* (pp. 517–536). Springer International Publishing. [CrossRef]

Center for Rural Education. (2025). *Rural literature library. Center for rural education website*. Available online: https://rural.vt.edu/rural-literature-library/ (accessed on 14 May 2025).

Christ, T., Chiu, M. M., Rider, S., Kitson, D., Hanser, K., McConnell, E., Dipzinski, R., & Mayernik, H. (2018). Cultural relevance and informal reading inventory performance: African-American primary and middle school students. *Literacy Research and Instruction*, *57*(2), 117–134. [CrossRef]

Collins, A., Joseph, D., & Bielaczyc, K. (2004). Design research: Theoretical and methodological issues. *The Journal of the Learning Sciences*, *13*(1), 15–42. [CrossRef]

Committee on Integrated STEM Education. (2014). *STEM integration in K-12 education: Status, prospects, and an agenda for research* (M. Honey, G. Pearson, & H. Schweingruber, Eds.). The National Academies Press. Available online: http://www.nap.edu/catalog.php?record_id=18612 (accessed on 1 April 2025).

Cote, M., & Nightingale, A. J. (2012). Resilience thinking meets social theory: Situating social change in socio-ecological systems (SES) research. *Progress in Human Geography*, *36*(4), 475–489. [CrossRef]

Crumb, L., Chambers, C., Azano, A. P., Hands, A., Cuthrell, K., & Max, A. (2023). Rural cultural wealth: Dismantling deficit ideologies of rurality. *Journal for Multicultural Education*, *17*(2), 125–138. [CrossRef]

Davis, B. G. (1993). Case studies. In *Tools for teaching* (pp. 222–227). JosseyBass.

Donehower, K., Hogg, C., & Schell, E. E. (2007). *Rural literacies*. Southern Illinois Press.

Donovan, E. (2016). Learning to embrace our stories: Using place-based education practices to inspire authentic writing. *Middle School Journal*, *47*(4), 23–31. [CrossRef]

Edmonson, J. (2003). *Prairie town: Redefining rural life in the age of globalization*. Rowman & Littlefield.

Eppley, K. (2017). Rural science education as social justice. *Cultural Studies of Science Education*, *12*(1), 45–52. [CrossRef]

Feinstein, N. W., Allen, S., & Jenkins, E. (2013). Outside the pipeline: Reimagining science education for nonscientists. *Science*, *340*(6130), 314–317. [CrossRef] [PubMed]

Food and Agriculture Organization of the United Nations. (2014). *The Water-Energy-Food Nexus: A new approach in support of food security and sustainable agriculture*. Available online: http://www.fao.org/3/a-bl496e.pdf (accessed on 20 August 2019).

Gagnon, D. J., & Mattingly, M. J. (2015). *Limited access to AP courses for students in smaller and more isolated rural school districts* (Article 235). The Carsey School of Public Policy at the Scholars' Repository. [CrossRef]

Gay, G. (2018). *Culturally responsive teaching: Theory, research, and practice*. Teachers College Press.

Gebrai, Y., Ghebremichael, K., & Mihelcic, J. R. (2021). A systems approach to analyzing food, energy, and water uses of a multifunctional crop: A review. *Science of The Total Environment*, *791*, 148254. [CrossRef]

Gruenewald, D. A. (2003). Best of both worlds: A critical pedagogy of place. *Educational Researcher*, *32*(4), 3–12. [CrossRef]

Herman, B. C. (2018). Students' environmental NOS views, compassion, intent, and action: Impact of place-based socioscientific issues instruction. *Journal of Research in Science Teaching*, *55*(4), 600–638. [CrossRef]

Ingersoll, R. M., & Tran, H. (2023). Teacher shortages and turnover in rural schools in the US: An organizational analysis. *Educational Administration Quarterly*, *59*(2), 396–431. [CrossRef]

Jacobson, M. J., & Wilensky, U. (2006). Complex systems in education: Scientific and educational importance and implications for the learning sciences. *The Journal of the Learning Sciences*, *15*(1), 11–34. [CrossRef]

Kellner, E. (2023). Identifying leverage points for shifting Water-Energy-Food nexus cases towards sustainability through the Networks of Action Situations approach combined with systems thinking. *Sustainability Science*, *18*, 135–152. [CrossRef]

Kingsolver, A. (2017). Practical resources for critical science education in rural Appalachia. *Cultural Studies of Science Education*, *12*(1), 219–225. [CrossRef]

Ladson-Billings, G. (1995). Toward a theory of culturally relevant pedagogy. *American Educational Research Journal*, *32*(3), 465–491. [CrossRef]

Lakin, J. M., Stambaugh, T., Ihrig, L. M., Mahatmya, D., & Assouline, S. G. (2021). Nurturing STEM talent in rural setting. *Phi Delta Kappan*, *103*(4), 24–30. [CrossRef]

Learning in Places Collaborative. (2022). *Framework: Complex socio-ecological systems*. Learning in Places. Available online: https://learninginplaces.org/frameworks/complex-socio-ecological-systems-framework/ (accessed on 10 February 2025).

Learning in Places Collaborative. (2025). *Storyline frameworks for educators*. Learning in Places website. Available online: https://learninginplaces.org/storyline-frameworks/ (accessed on 10 February 2025).

Lee, H. (1960). *To kill a mockingbird*. J.B. Lippincott & Co.

Longhurst, J. M. (2022). Developing, utilizing, and critiquing definitions of "rural" in rural education research. In A. P. Azano, K. Eppley, & C. Biddle (Eds.), *The Bloomsbury handbook of rural education in the United States* (pp. 1–18). Bloomsbury Academic.

Marin, A., & Bang, M. (2018). Look it, this is how you know: Family forest walks as a context for knowledge-building about the natural world. *Cognition and Instruction*, *36*(2), 89–118. [CrossRef]

Meadows, D. H. (2008). *Thinking in systems: A primer* (D. Wright, Ed.). Chelsea Green Publishing.

Morales, A. R. (2019). Valuing rural dexterity: Experiential funds of knowledge, science education, and rural kids. *Great Plains Research*, *29*(1), 33–40. [CrossRef]

National Academies of Sciences, Engineering, and Medicine (NAESM). (2024). *K-12 STEM education and workforce development in rural areas*. The National Academies Press. [CrossRef]

National Academy of Engineering (NAE) & National Research Council (NRC). (2014). *STEM integration in K-12 education: Status, prospects, and an agenda for research*. The National Academies Press. [CrossRef]

National Oceanic and Atmospheric Administration. (2024, March 29). *Hurricane costs: Fast facts*. NOAA's National Centers for Environmental Information. Available online: https://coast.noaa.gov/states/fast-facts/hurricane-costs.html#:~:text=Helene%20was%20the%20deadliest%20Atlantic,,%20on%20October%209,%202024 (accessed on 31 March 2025).

National Research Council (NRC). (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. The National Academies Press. [CrossRef]

NC-FEW. (2022). *An NC-FEW community vision for FEW-Nexus-based education (version 1)*. Available online: https://serc.carleton.edu/nc-few/vision.html (accessed on 10 February 2025).

Organisation for Economic Co-operation and Development (OECD). (2006). *Assessing scientific, reading and mathematical literacy: A framework for PISA 2006*. OECD.

Pahl-Wostl, C., Gorris, P., Jager, N., Koch, L., Lebel, L., Stein, C., Venghaus, S., & Withanachchi, S. (2021). Scale-related governance challenges in the water–energy–food nexus: Toward a diagnostic approach. *Sustainability Science*, *16*(2), 615–629. [CrossRef]

Paris, D., & Alim, H. S. (2017). *Culturally sustaining pedagogies: Teaching and learning for justice in a changing world*. Teachers College Press.
Parton, C. (2025). *Literacy in place*. Available online: http://www.literacyinplace.com (accessed on 14 May 2025).
Peine, E., Azano, A. P., & Schafft, K. (2020). Beyond cultural and structural explanations of regional underdevelopment: Identity and dispossession in Appalachia. *Journal of Appalachian Studies*, *26*(1), 40–56. [CrossRef]
Pugh, P., McGinty, M., & Bang, M. (2019). Relational epistemologies in land-based learning environments: Reasoning about ecological systems and spatial indexing in motion. *Cultural Studies of Science Education*, *14*(2), 425–448. [CrossRef]
Romulo, C., Venkataraman, B., Caplow, S., Ajgaonkar, S., Allen, C. R., Anandhi, A., Anderson, S. W., Azzarello, C. B., Brundiers, K., Blavascunas, E., Dauer, J. M., Druckenbrod, D. L., Fairchild, E., Horne, L. R., Lee, K., Mwale, M., Mischler, J., Pappo, E., Patel, N. S., . . . Vincent, S. G. (2024). Implementing interdisciplinary sustainability education with the food-energy-water (FEW) nexus. *Humanities & Social Sciences Communications*, *11*(1), 928. [CrossRef]
Roth, W.-M., & Calabrese Barton, A. (2004a). Chapter 1: Science as collective praxis, literacy, power, and struggle for a better world. In *Rethinking scientific literacy* (pp. 1–19). RoutledgeFalmer.
Roth, W.-M., & Calabrese Barton, A. (2004b). *Rethinking scientific literacy*. RoutledgeFalmer.
Ruday, S., & Azano, A. P. (2019). Arguments that matter: A place-based approach to teaching argument writing to rural students. *Journal of Teaching Writing*, *34*(1), 1–23.
Ruday, S., Azano, A. P., & Kuehl, R. (2021). Books as portals: Using place to understand rural students' individuated reading experiences. *English in Education*, *56*(2), 122–138. [CrossRef]
Sadler, T. D. (2011). Socio-scientific issues-based education: What we know about science education in the context of SSI. In T. D. Sadler (Ed.), *Socio-scientific issues in the classroom: Teaching, learning and research* (pp. 355–369). Springer. [CrossRef]
Sadler, T. D., Barab, S. A., & Scott, B. (2007). What do students gain by engaging in socioscientific inquiry? *Research in Science Education*, *37*(4), 371–391. [CrossRef]
Showalter, D., Hartman, S. L., Eppley, K., Johnson, J., & Klein, R. (2023). *Why rural matters 2023: Centering equity and opportunity*. National Rural Education Association. Available online: https://www.nrea.net/why-rural-matters (accessed on 31 March 2025).
Simpson, G. B., & Jewitt, G. P. W. (2019). The development of the Water-Energy-Food Nexus as a framework for achieving resource security: A review. *Frontiers in Environmental Science*, *7*, 8. [CrossRef]
Soja, E. (2010). Spatializing the urban, Part 1. *City: Analysis of Urban Change, Theory, Action*, *14*(6), 629–635.
Spence, P., Gerald-Goins, T., Weems, K., Jackson, C., & Goins, G. D. (2021). Food, energy and water learning module workbooks: Low-cost affordable inquiry-based STEM curricula. *Journal of STEM Outreach*, *4*(1), 1–15. [CrossRef]
Tieken, M. (2014). *Why rural schools matter*. UNC Press Books.
Valve, H. (2018). Resource governance and the politics of the social: Ordering in and by socio-ecological systems. *Geo: Geography and Environment*, *5*(2), e00064. [CrossRef]
van den Broek, K. L., Luomba, J., van den Broek, J., & Fischer, H. (2023). Content and complexity of stakeholders' mental models of socio-ecological systems. *Journal of Environmental Psychology*, *85*, 101906. [CrossRef]
Wade, A. A., Grant, A., Karasaki, S., Smoak, R., Cwiertny, D., Wilcox, A. C., Yung, L., Sleeper, K., & Anandhi, A. (2020). Developing leaders to tackle wicked problems at the nexus of food, energy, and water systems. *Elementa: Science of the Anthropocene*, *8*(1), 11. [CrossRef]
Walker, D. (2011). Critical science literacy in rural Northeastern New Mexico. In C. A. Rossatto (Ed.), *Teaching for global community* (pp. 233–247). Emerald Publishing.
Waller, R., & Barrentine, S. J. (2015). Rural elementary teachers and place-based connections to text during reading instruction. *Journal of Research in Rural Education*, *30*(7), 1–13.
Wiggins, G. P., & McTighe, J. (2005). *Understanding by design*. Association for Supervision and Curriculum Development.
Yosso, T. J. (2005). Whose culture has capital? A critical race theory discussion of community cultural wealth. *Race Ethnicity and Education*, *8*(1), 69–91. [CrossRef]
Zeidler, D. L., Sadler, T. D., Applebaum, S., & Callahan, B. E. (2009). Advancing reflective judgment through socioscientific issues. *Journal of Research in Science Teaching*, *46*(1), 74–101. [CrossRef]
Zimmerman, H. T., & Weible, J. L. (2017). Learning in and about rural places: Connections and tensions between students' everyday experiences and environmental quality issues in their community. *Cultural Studies of Science Education*, *12*(1), 7–31. [CrossRef]

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