

The Food-Energy-Water Nexus: An Organizing Framework for Supporting Secondary Teacher
Agricultural Literacy and Socio-Ecological Systems Thinking

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Introduction/need for innovation

This work was conducted as part of a continuing professional education program that was designed to train non-agriculture secondary teachers in the food and agricultural sciences. Offered through the College of Agriculture and Life Sciences at Virginia Tech, the four-day program connects emerging research to the current secondary curriculum through teachers working with food and agricultural science graduate students and faculty in campus laboratories to learn about current research and laboratory techniques. The program has increased the secondary teachers' knowledge and confidence to incorporate new agriculture and life sciences laboratory experiences and content into their classrooms (Taylor et al., 2024). A challenge with the program design, however, is that the topics addressed in each program iteration are based on the research of participating scientists, ranging from food science and sensory evaluation to bovine artificial insemination to watersheds and water quality. Thus, we identified the need to develop a unifying theme for the program that supports integration of the new concepts. We grounded this theme in systems thinking and the Food-Energy-Water (FEW) Nexus.

Many real-world challenges in food and agriculture, such as food security, are inherently complex and interdisciplinary (e.g., Khumairoh et al., 2012; Ruiz et al., 2022) and can be framed using a socio-ecological systems perspective, in which humans and nature are considered inextricably intertwined (Caniglia & Mayer, 2021). A systems approach anticipates complex interconnections among different actors and elements in the system that help predict outcomes that may otherwise be surprising (Meadows, 2008). Reasoning about complex socio-ecological systems requires not only scientific knowledge, but consideration of the ways in which power, goals, and interests drive functioning of the system (Cote & Nightingale, 2012). Additionally, systems thinking can be used to account for the perspectives and roles of diverse groups of people within a system (Ulrich & Reynolds, 2010). This is an important consideration in developing teachers who can design lessons that are responsive to local issues and sustain the cultures with which their students identify (Alim & Paris, 2017).

The FEW Nexus has been utilized as a framework to promote agricultural literacy and drive systems thinking because it prompts consideration of interconnections between three sectors that are essential for modern human society (Scherer et al., 2020). Furthermore, management decisions within the FEW Nexus must consider not only technological solutions, but social and environmental implications (Food and Agriculture Organization of the United Nations (FAO), 2014), aligning with socio-ecological systems thinking (Cote & Nightingale, 2012). FEW-Nexus-based education has shown promise in higher education contexts in recent years (Romulo et al., 2024). While implementation is nascent in K-12 settings, the FEW Nexus has also been proposed as a valuable framework for STEM education (Campbell et al., 2024).

How it works/methodology/program phases/steps

The unifying theme for the program is *Using Systems Thinking to Address Complex Real-World Problems in the FEW Nexus*. Systems thinking was operationalized with the educational framework for reasoning about complex socio-ecological systems developed by the Learning in Places Collaborative (2022). The Learning in Places framework includes five dimensions: species, kinds, and behaviors; relationships; places, lands, and waters; thinking across scales; and ethical deliberation and decision-making. In this framework, power and historicity influence all aspects of socio-ecological systems. The FAO's model of the FEW Nexus (2014) was used to

describe this complex system. FEW Nexus-based education was framed through these principles: using interdisciplinary educational contexts to integrate food, energy, and water systems; centering decision-making about management of natural resources, which support sustainable use and development; and using a nexus perspective to address tradeoffs (NC-FEW, 2022).

The unifying theme was supported through an introductory half-day session, daily reflection sessions, and a final synthesis session. Throughout the sessions, teachers participated in individual, small-group, and large-group activities informed by a social constructivist approach. The introductory session provided an overview of systems thinking, complex socio-ecological systems, and the FEW Nexus framework. Daily reflection sessions occurred following technical skill training and included (1) synthesis of learning outcomes, (2) drawing connections between new concepts, the FEW Nexus, and socio-ecological systems, and (3) reflection on how the new concepts relate to issues facing their local school communities. In the final synthesis session, teachers connected all the new concepts from the technical sessions back to the FAO FEW Nexus model (2014) and used systems mapping to develop ideas for lessons they wanted to develop that connect what they learned to FEW Nexus issues in their local communities.

Results to date/implications

The program has been implemented with four cohorts of educators, ranging from 9-28 participants per year. Participants successfully engaged with all activities, demonstrating socio-ecological systems thinking in discussions, artifacts from group activities, and individual reflections. For example, in reflecting on a session about microbial DNA sequencing, participants wrote: “potential relationship impact between plants, water, and humans and how they correlate to each other → all things are connected.” Participants also described ways in which they could use the framework with their students, such as “have students take a good look at their community and their interaction within a system.” Overall, participants found value in the approach: “It helped me to see that we are part of a system. Before, I would focus on single parts, but I did not really put them together.”

Future plans

Formal analysis of artifacts from program implementation (large-group synthesis pages, individual reflections, facilitator notes, etc.) is ongoing and will result in design research findings about the efficacy of the theme in supporting socio-ecological systems thinking. A facilitation guide with supporting resources has been developed and will be published as an open educational resource for others to adapt and use in other professional learning experiences.

Resources needed

The overall program was funded by a USDA-NIFA Professional Development for Agricultural Literacy Grant awarded to Donna Westfall-Rudd (PD). Resources needed to implement *Using Systems Thinking to Address Complex Real-World Problems in the FEW Nexus* as part of a program are minimal. The facilitation guide and supporting materials will be freely available.

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