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Education and Wicked Problems

Preparing Our Students to Address the Wicked Problems

by Gaea Hock

You may be asking, "What Are Wicked Problems?" Wicked problems are those in which there is not a clear answer in how to approach solving the challenge. It requires many different disciplines, expertise, and viewpoints to solve the problem. Agriculture is facing many wicked problems: feeding a growing population, sustainable production practices, managing water resources, responding to consumer demands, and implementing risk management practices.

I recently became more aware and appreciative of those working to solve these grand challenges. I am part of a National Science Foundation grant focused on preparing the next generation of problem solvers. The NRT program brings together several disciplines to train a group of graduate students to think in a more interdisciplinary manner. It is a challenge to train our minds to work in this manner and even harder to get our students to be okay with no one correct response.

When I think about how I could have made my high school classes and curriculum more interdisciplinary in order to address the wicked problems, I reflected on how I could have created more assignments that spanned across disciplines. While I had a great English teacher who would allow speeches written in my classroom to be used for assignments in hers, I know there were other opportunities that I never took the time to explore.

We can also consider the competition events our students participate in through FFA. The Ag Issues Forum and Agriscience Fair come to mind as great examples. Having our students participate in these events can help them think about problems in a new and more meaningful manner. Another event I personally competed in, as an adult, is the Farm Bureau Discussion Meet. Kansas started offering this competition at the high school level a few years ago and I believe it is a great way to encourage students to think about problems and have meaningful discussions as to the solutions.

As I recruited a theme editor for this issue, I was excited Dr. McKim agreed and proposed a theme to get us thinking about how we are preparing our students to handle the challenges facing the world we live in today. The term "wicked problem" has been used for several years at the collegiate level, but I am not sure how often we apply that term to curriculum taught at the secondary level.

When you teach concepts related to the wicked problems, allow time for students to consider how that information fits into more than one discipline, how they would solve the program, and the alternative solutions. It may make them uncomfortable at first to not have one correct answer, but the skills they will be building will enable them to have the confidence to seek out the answers.

While we may think solving the world's wicked problems is better suited for professionals, I argue that equipping our students with the skills needed to address them is one way we are serving future generations. As you read the articles in this issue, consider how you could incorporate the ideas, tips, and strategies in your own classroom and program.

Dr. Gaea Hock is an Associate Professor of Agricultural Education at Kansas State University and Editor of ***The Agricultural Education Magazine.***

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Agriculture, Food and Natural Resources Education and Wicked Problems

by Aaron McKim

I always enjoy reading *The Agricultural Education Magazine*. I love that we, in school-based agricultural education, have a forum where educators, scholars, and stakeholders come together to connect theory and practice. When asked to serve as a theme editor, I was hopeful the final product would adhere to the tradition of quality and practicality synonymous with The Agricultural Education Magazine. As the process of assembling the issue went along – selecting a theme, identifying authors, and refining topics – I got more and more excited by the prospect of the end product. As each article was submitted and I had a chance to read the work of my colleagues, I was challenged, inspired, and empowered. The hopeful outlook I held at the onset turned into a confident stance that this issue will serve as a foundation for transformed theory and practice within school-based agricultural education.

To all the authors who contributed to this issue, thank you for sharing your innovative thinking, practical approaches, and commitment to positive growth within our discipline. To the readers, I hope you enjoy reading these works as much as I have – provided below is a short introduction to what you will read.

The first cluster of articles lay an essential foundation for teaching about wicked problems. Hannah Scherer, Cory Forbes, Nicole Sintov, and Hui-Hui Wang introduce us to the food-energy-water (FEW) nexus and highlight innovative applications within agricultural education. Then, Matt Raven weaves together systems thinking and holistic management, illuminating opportunities to push our approaches to be more regenerative and holistic. Catlin Pauley adds a wonderfully crafted guidebook for integrating social-ecological resilience thinking within our programs. The theory cluster continues with Adam Cletzer providing an overview of how leadership thinking has evolved and the importance of teaching and practicing eco-leadership within our programs. Last but not least, Taylor Ruth, Joy Rumble, Alexa Lamm, and Jason Ellis reinforce the importance of understanding decision making within the wicked problems facing agriculture, food, and natural resources.

The second cluster of articles showcase examples of how teaching about wicked problems can be done in a variety of educational settings. In the first article within this cluster, Craig Kohn introduces us to Carbon Time, an innovative set of curricula designed to foster three-dimensional science and agriculture learning. Then, Haley Traini reflects on her work in Ghana with AgriCorps, challenging us all to think about how traditional approaches can prove effective to emergent and complex challenges. Melanie Bloom then shares how the Curriculum for Agricultural Sciences Education (CASE) intentionally prepares learners to address wicked problems in agriculture, food, and natural resources. Ending on a high note, Sarah Cramer takes us inside her classroom to showcase how wicked problems are taught within a liberal arts context, identifying tested approaches to engaging learners in understanding wicked problems.

As you embark on this adventure of learning, I invite you to engage in the conversation about wicked problems. If you read an article that resonates with you, email the authors to share your appreciation and perspective. If you feel compelled, write an article for *The Agricultural Education Magazine* to share your point of view on this topic or any other. At your next professional development, invite your colleagues to join in a round-table discussion about teaching wicked problems. When you see an opportunity to change how or what you teach, give it a try and share your experience with others. To expand the knowledge on this topic, discuss possible research collaborations with your students and faculty at a nearby college or university. As a discipline, we need your voice, your ideas, and your perspective to grow together to better educate all students about wicked problems.

Aaron McKim is an Assistant Professor in the Department of Community Sustainability at Michigan State University.

The Food-Energy-Water-Nexus: A New Way to Help Students Think About Resource Management in AFNR Education

by Hannah H. Scherrer, Cory Forbes, Nicole Sintov and Hui-Hui Wang

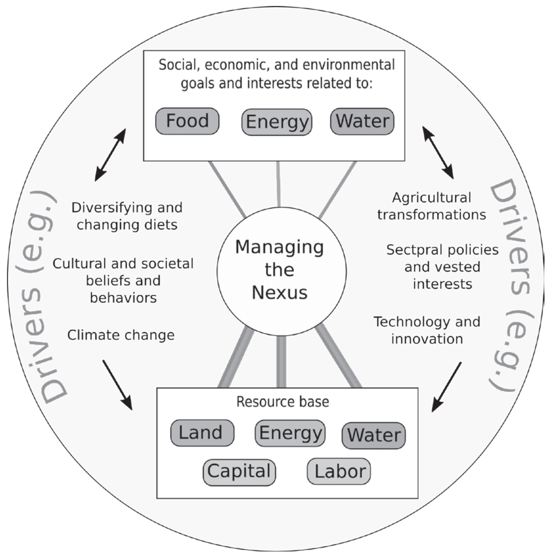
The Food-Energy-Water (FEW)-Nexus can serve as a framework for research and technological innovation in response to challenges such as global food security. Over the past few years, we have been part of a growing community of educators and education researchers seeking to use this framework to innovate educational experiences for learners in a wide range of educational contexts. In this article, we introduce the concept of the FEW-Nexus, discuss motivations for using the FEW-Nexus in AFNR education, and share ideas for getting started designing learning experiences within secondary AFNR pathways. We end with a call to action and next steps for engaging with this community of educators.

What is the Food-Energy-Water-Nexus?

Consider the following real-world situation. In what ways are processes in different systems interacting?

The High Plains Aquifer is a water source for a significant percentage of United States agriculture, accounting for one-sixth of the world's grain produced and $3.5 billion in agricultural production. Agricultural commodities produced with this resource include both food (grain and livestock) and energy (e.g., ethanol). However, groundwater levels in many parts of the region have declined at unsustainable rates despite improvements in both the water use efficiency and increased productivity through improved agricultural practices. Changes to Earth's climate system, leading to increased climate variability and extreme weather events, will continue to exacerbate these challenges. Management of the region's groundwater resources will impact food and energy production systems and be central to its economic and, by extension, social, cultural, and political stability.

This is an example of a complex system in which changes in one aspect of the system can cause changes in another (often far reaching) part of the system. This type of system has been termed a coupled human-natural system because humans are both drivers of and impacted by changes in natural systems and vice versa. The idea of the FEW-Nexus developed as a framework in which to understand the interplay between natural systems and their human dimensions in the space where these three resources, each vital to human society, intersect. While each of these represents a coherent system and unit of analysis in its own right, envisioning their interconnections as a 'nexus' aids in management decisions that span particular objectives, production and consumption pathways, and regulatory modes. In short, the nexus idea affords greater ability to represent systems as holistic entities that go beyond a simple sum of their constituent parts. Doing so allows for more integrative problem-solving and decision-making that accounts for and balances trade-offs and synergies within and across systems. These processes will only become more critical given the challenge of feeding a growing human population sustainably with a finite supply of natural resources.



Why should we use the FEW-Nexus in AFNR education?

The FEW-Nexus can help AFNR educators identify real-world problems that are complex, locally-relevant, and globally connected. Framing AFNR education using FEW-Nexus-based "wicked" problems can support long standing goals of STEM/AFNR science literacy to prepare members of contemporary society to make choices about issues such as diet, lifestyle, transportation, and consumption that have local and global impacts (e.g., Bybee, McCrae, Laurie, 2009; Frick et. al, 1991; Meischen & Trexler, 2003). Furthermore, emerging ideas within the FEW-Nexus education community propose that STEM/AFNR science literacy should extend to include an enhanced capacity to understand, analyze, and make effective, science-informed decisions about complex, real-world challenges in the FEW-Nexus (ncfew.org). This is particularly relevant for secondary agricultural educators who are preparing the next generation to enter the AFNR workforce. A deeper understanding of the interconnectedness of FEW systems will equip students to adapt to and anticipate effects of changing conditions, such as increased water scarcity, in making decisions about resource management in AFNR production systems.

Teaching and learning in the FEW-Nexus through *interdisciplinary problem solving* can promote skill development, new perspectives and disciplinary learning outcomes. Real-world AFNR resource issues and production challenges in the FEW-Nexus are inherently localized, but also connected to national- and global-scale systems. Problem-solving in the FEW-Nexus allows students to move between these scales and *develop systems thinking skills* (see Matt Raven's article in this issue). Identifying potential solutions that are feasible and supported by real-world data requires the use of *evidence-based reasoning.* The inherent coupling between human and natural systems in the FEW-Nexus allows students to see problems from multiple perspectives and consider the implications of potential solutions for *diverse groups of people affected.* This can also *motivate civic engagement* when there are potential actions that students can take. Finally, the interdisciplinary nature of the FEW-Nexus allows learners to deepen their STEM and AFNR disciplinary knowledge through discovering new connections and applying concepts in new ways. Outcomes supported by a FEW-Nexus educational approach are consistent with the *Next Generation Science Standards* (NGSS Lead States, 2013), including the crosscutting concepts of systems and system models; energy and matter: flows, cycles, and conservation; and stability and change.

How can we use the FEW-Nexus in AFNR education?

Transforming AFNR educational practice to implement the full potential of the FEW-Nexus perspective will require a commitment from the profession to work collaboratively to identify what works and what doesn't in the context of a broad range of real-world agricultural education classrooms. From previous work in other contexts, we know case- or problem-based learning experiences that foreground core disciplinary concepts AND their embeddedness in coupled human-natural systems work well (Forbes, Brozovic, Franz, Lally, & Petitt, 2018). The complex, multi-faceted FEW-Nexus challenge itself, as presented to the students, serves as the entry point for considerations of both scientific and non-scientific dimensions of an issue. These learning experiences by necessity transcend disciplinary boundaries when students are tasked with proposing informed solutions that take into account concrete implications for an array of stakeholders.

As described by the Food and Agriculture Organization of the United Nations (2014), the FEW-Nexus helps in both "understanding and managing the complex interactions between water, energy, and food" (p. 1). Anticipating these complex interactions and their potential implications can lead to better management decisions across sectors. These types of insights can serve as the basis for innovative educational experiences that help learners to develop a systems perspective. As a step forward, we can begin to identify FEW-Nexus challenge areas that support learning within and illuminate linkages between AFNR pathways. For AFNR educators, there are existing opportunities within the National AFNR Content Standards (https://thecouncil.ffa.org/afnr/) that provide the FEW-Nexus context in which to develop specific, locally-relevant case- or problem-based learning experiences. Within a specific pathway, the FEW-Nexus can help learners link out to other disciplines and consider broader impacts of decisions within a particular AFNR area. Here we describe a few examples of how existing standards can be viewed through a FEW-Nexus lens to help students see greater connections and a broader perspective on potential impacts of production and resource management decisions.

Animal Systems Career Pathway Standard AS.08.01: Design and implement methods to reduce the effects of animal production on the environment

This standard focuses on the animal production component of the food system. In itself, this component is linked to other aspects of agriculture (e.g., crops grown for animal consumption) and the food system (e.g., food safety, consumer preference, etc.). Animal production is also connected to water systems through inputs (e.g., water use in facilities) and outputs (e.g., potential waterway impairment from wastewater contamination). Animal production facilities also use energy and are further connected to energy through activities such as energy consumption in crop production and tradeoffs between use of corn for feed versus ethanol. Using a FEW-Nexus perspective can help students uncover potential environmental impacts and connections to sectors that they may not have considered before.

Power, Structural and Technical Systems Career Pathway Standard PST.05.01: Apply computer and other technologies (e.g. robotics, CNC, UAS, etc.) to solve problems and increase the efficiency of AFNR systems

This standard inherently connects to the FEW-Nexus when efficiency is viewed within all three sectors. Solutions to FEW-Nexus challenges may involve technological innovations that increase production while minimizing water and energy inputs. Using a systems perspective in defining problems and developing solutions can help students to consider broader implications of their innovations and the diverse stakeholder groups that will be affected.

Plant Systems Career Pathway Standard PS.03.02: Develop and implement a management plan for plant production

This standard addresses an essential component of a plant production operation. When viewed through a FEW-Nexus lens, there is significant potential to connect the informed decision-making process that is required to develop a management plan to broader issues such as climate change. In a recent study, agricultural educators reported strong understanding of the science behind global climate change but little time teaching about it (Wang, Bhattacharya, & Nelson, 2019). In using a FEW-Nexus perspective when developing and defending choices within their management plans, students can address climate-related considerations such as energy use within different types of growing environments and predicted changes in regional water availability due to climate change.

Further considerations for problem solving in FEW-Nexus educational experiences

Within each of these examples, it becomes easy to see how food, energy, and water systems are interconnected. As you start to think about developing scenarios for FEW-Nexus-based case- or problem-based learning opportunities for your students, it is important to guide them to think deeper about interconnections that may not be obvious. Here are some ideas for ways to prompt students:

- Who is affected in this scenario? Who are the obvious stakeholders and who might be impacted that we haven't considered yet?
- In what ways could food, energy, and water systems affect each other in this scenario?
- How could we anticipate unintended consequences that might arise from FEW-Nexus interactions?
- What are some potential outcomes of our proposed solution in terms of social, environmental, and economic sustainability?

What's next?

Using the ideas in this article as a starting point, we encourage you to think about how you can use the FEW-Nexus to innovate within your own program. If there are things you are already doing that connect to the FEW-Nexus perspective, you can use the framework presented here to further refine your ideas in order to deepen student learning. As you develop new FEW-Nexus-related educational experiences, we encourage you to share them with your colleagues — you can serve as a catalyst for further innovation within AFNR education!

If you would like to learn more about the growing community of educators and education researchers engaging with these ideas, visit the website for the *National Collaborative for Research of Food, Energy, and Water Education (NC-FEW)* at ncfew.org. There you can learn more about our current efforts, view recent newsletters and webinars, and get involved with the community.

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THEME ARTICLE

Using the Holistic Management Framework to Teach Systems Thinking

by Matt Raven

The things we manage always involve people and human organizations (referred to as soft systems) or natural resources (natural systems). What we manage in both soft and natural systems often produce unplanned or unexpected results and they are self-organizing: if a person or a species dies, the organization or the biological community adjusts and continues, albeit in changed form. The classic example of a complex system was the study published by Robert Paine in 1966 where in a tidal pool he eliminated a starfish that was a keystone species – within a year the number of species in the tide pool had been cut in half – a self-organizing system with unintended consequences. The global food system is prime example of a complex system combining both social and natural systems.

The global food system is extremely complex, and the problems associated with it are typically called "wicked" because they are almost impossible to solve. It is this complexity that has made soft and natural systems so difficult to manage, leading so often to disappointing results and unintended consequences. Global climate change, genetically modified organisms (GMO), water resource management, biofuel production (corn to ethanol), air quality, animal welfare, healthcare, soil erosion are all wicked problems associated with food and agricultural systems with global climate change at the head of the list.

Wicked Problems

Batie's (2008) description of wicked problems includes the characteristics of a multitude of interdependencies and causations. For example, climate change, there is no one cause. Furthermore, there are almost always unintended consequences to solutions – look no farther than Asian carp knocking on the door of the Great Lakes or Kudzu in the Southeast. Wicked problems are hard to define as they are constantly evolving and are socially complex – it is hard to define climate change when many of those in public office claim it as a hoax. Since they are multi-causal, they are rarely the responsibility of one organization and most importantly they involve changing people's behaviors.

Batie (2008) argued that linear or reductionist science is not well positioned for solving wicked problems due to their characteristics, especially the conflict over values regarding the outcomes. Since they are not the responsibility of one organization, they do not fit into one discipline readily. Consequently, many disciplines must be involved, and stakeholders must be brought into the equation due to conflict over values. These types of problems and the need for interdisciplinary approaches to addressing them require those attempting to ameliorate them to be accomplished system thinkers.

System thinking differs from the types of analysis typically used in linear science. The analysis used in linear science is reductionist in nature in that it reduces a system to its parts and then studies those parts independently from the whole system. Aronson (1998) argued that systems thinking in contrast focuses on how a part of the system interacts with the other elements of the system to which it belongs. System thinking expands the view of a system taking into account more and more interactions of system elements instead of divorcing smaller parts from the system and then studying those independently. When a system is studied holistically in this manner it is not unusual to arrive at very different conclusions than those from a reductionist analysis. Aronson (1998) maintained that systems thinking is much more effective when dealing with complex problems especially those that are inherently dynamic such as wicked problems. He cited examples of where systems thinking has proven especially effective such as complex problems with many stakeholders; reoccurring problems that have been made worse by previous attempts to fix them; and problems whose solutions are not obvious.

So many of the issues in food and fiber systems are complex problems, involving many stakeholders and have often been made worse from previous actions to fix them. Colony Collapse Disorder with honeybees, declining populations of pollinators like the Monarch butterfly, Mountain pine beetles and soil erosion are just a few examples of these complex problems that would benefit from a more systems-oriented approach in response to these challenges. There is a critical need for current and future agricultural professionals to be accomplished system thinkers. However, currently there is not an emphasis on teaching systems thinking to students in School Based Agricultural Education (SBAE) programs. Agriculture, Food and Natural Resource (AFNR) educators can change this by starting to provide students the skills and experiences needed to become accomplished systems thinkers. This can be done by contextualizing the content being taught to the systems which it is embedded. Furthermore, students need to be taught an approach that provides them a framework to think and make decisions in a more holistic manner.

Holistic Management

Fortunately, such a framework does exist and has proven effective for decades in managing complex systems, especially land and natural resources systems holistically, Holistic Management. Holistic Management (HM) has an overarching framework that provides land managers the tools and strategies needed to manage complex systems while taking into account environmental, social and financial factors both in the short term as well as the long term (Savory & Butterfield, 2016). HM is a decision making/management framework based on systems thinking. The key insight to HM is that everything under management must be managed as the whole taking into consideration the interaction of all the parts and their contribution to the whole. Allan Savory, the developer of HM, founded the Savory Institute that oversees the Savory Network consisting of 43 hubs on every continent except Antarctica. The Savory Network is a global community working to advance regenerative agriculture through the practice and dissemination of HM. There are currently 10 million hectares under holistic management and 7,931 holistically trained land managers.

Savory developed Holistic Management out of necessity. He was a consultant in Rhodesia (now Zimbabwe) and ranchers were suffering financial losses due to nonfunctioning ecosystem processes. They were trying to manage complex systems using linear methods resulting in degradation of land and financial ruin. He had four insights that led to the Holistic Management Framework with categories of strategies and tools that can be used to manage land and natural resources holistically as well as any other complex system. These Framework categories consist of the Whole Under Management; Holistic Context; Ecosystem Processes; Ecosystem Management Tools; Planning and Selection of Strategies and Actions; Context Checks; Feedback Loop; Management Guidelines and Planning Procedures. A graphical representation of the Framework can be found in Figure 1. The foundational tenet to managing holistically is the development of a Holistic Context that is applied to the whole under management. The Whole Under Management could be a ranch, a business, a student's SAE or a SBAE land lab. A person's Holistic Context consists of "…quality of life, an expression of the way people want their lives to be within the whole under management; and the future resource base, a description of the environment and behaviors that will sustain that quality of life for their successors" (Savory & Butterfield, 2016, p. 79). Every management decision made, small or large, is checked against this context.

A principal category of the Framework is the Ecosystem Processes given HM is first and foremost a holistic framework for managing land and natural resources. Savory uses the analogy that each process (mineral cycle, water cycle, energy flow and community dynamics) is a window each looking into the same room (symbolizing the entire ecosystem) and that each ecosystem process is interconnected. When one is impacted the others are affected as well. Modern agriculturalists must understand ecosystem processes and how their management decisions impact them either in a positive or negative way. Only when these ecosystem processes are taken into consideration will agricultural systems be able to produce food and fiber while at the same regenerating these processes. Teaching these ecosystem processes within the context of food and fiber systems will help students' system thinking as it applies to the water-food-energy nexus.

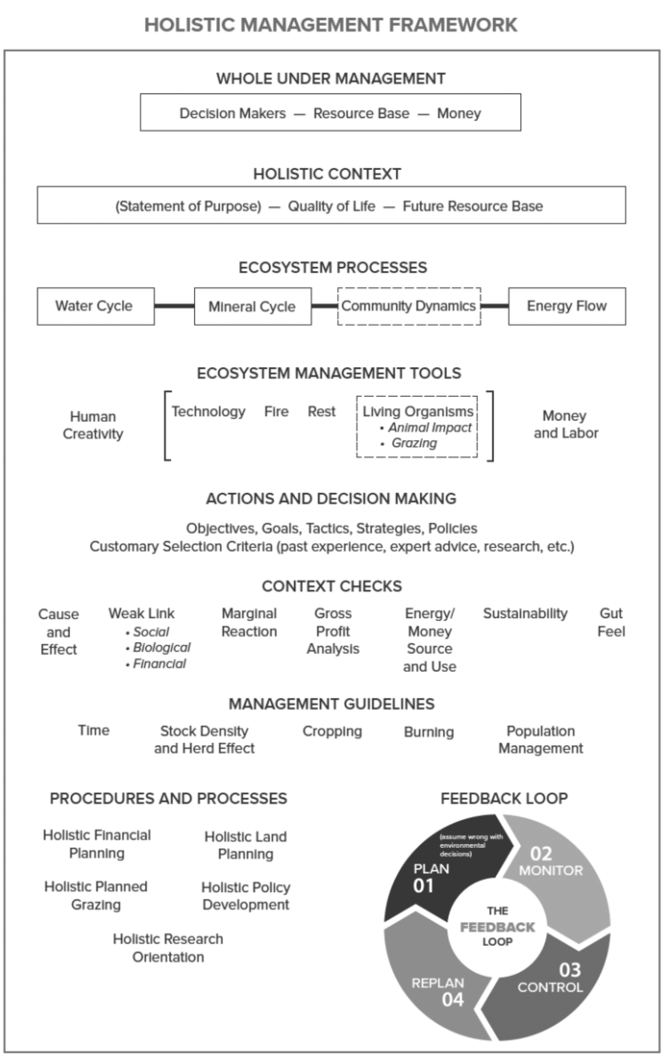

Figure 1. The Holistic Management Framework

Next in the Framework are the Ecosystem Management Tools that land managers have at their disposal to alter the Ecosystem Processes. Labor and money bracket the other tools as one or both are always required in the use of the other tools. The tools technology, rest, fire and living organisms are the ones most familiar to those who manage land conventionally. Animal impact and grazing, when managed holistically, are specialized uses of living organisms and are especially important in brittle environments where moisture in the form of rain and humidity isn't consistent.

Planning and Selection of Strategies and Actions immediately proceed the Context Checks within the Framework. The Holistic Context is interconnected with this aspect of the Framework as it is with all sections. Rather than having a plan, objective and/or goal that was likely narrowly focused on a need or problem the Holistic Context expands the view and takes into consideration the Whole Under Management. Once again forcing the manager to be systematic in their thinking when making a decision to which tool to use or whether to take any action.

To aid with these decisions there are seven context checks which are a series of questions to ferret out any actions that do not fit into the Holistic Context and are not socially, environmentally or economically sound both in the short and long-term. Three of the seven are economic in nature as you cannot improve ecosystem processes if you are not profitable and able to remain in business. Finances are an important part of HM and by putting them into context with all the other aspects of the food and fiber system the learner better understands the significance of them.

When making a decision in HM the first assumption is that it is probably an incorrect decision and hence the need for a Feedback Loop. When managing a system holistically the manager must plan-monitor-control-replan. This is a continuous process because when managing a complex system there are always unforeseen consequences. Monitoring will detect these circumstances and allow for the opportunity to replan if necessary.

The final categories of the Framework are Management Guidelines and Planning Procedures. The Management Guidelines are specific to the use of the Ecosystem Management Tools while Planning Procedures are refinements to financial planning, land planning, research and policies. Holistic Planned Grazing is the procedure most associated with HM and is the use of animal impact and grazing to recover grasslands. Figure 2 shows cattle being grazed at the Michigan State University Lake City Research Center using Holistic Planned Grazing. All the parts of the Framework are interconnected and when implemented holistically provide checks for managers to confirm that actions taken within a Holistic Context are generally assured of being approximately right with the Feedback Loop providing information to replan if necessary.

Figure 2

Applying HM to SBAE

Holistic Management and its Framework was created for managing land and natural resources taking into account the complexity of those systems. It is an ideal teaching tool for AFNR educators to use in SBAE as it combines important strategies and tools for managing complex food and fiber systems while concurrently providing learning opportunities for students to become accomplished system thinkers. An introductory SBAE course could be organized using the categories of the HM Framework as a course outline. Ideally the course would be focused on the management of a land lab where students could apply what they are learning in a real-life situation while being able to monitor the impact of their management decisions.

Students completing an introductory course that uses the Framework as a course outline would have a solid foundation in both systems thinking as well as key concepts in food and fiber systems. They would learn the fundamentals of system thinking from the introduction of the concept of the management under whole. The development of a holistic context for the class would give them the opportunity to apply this knowledge. Using the ecosystem processes as the context to teach Next Generation Science Standards would likely enhance learning by connecting the standards to authenticate food and fiber systems applications. Learning about food and fiber system management practices within the context of their impact on ecosystem processes would further students' system thinking abilities while simultaneously acquiring technical knowledge. The land monitoring protocol used in the feedback loop would provide students additional learning in how to evaluate the health of land as well as to see firsthand the impacts of their management decisions. Figure 3 is an example of a healthy pasture teaming with biological activity in the soil. The planning procedures such as Holistic Financial Planning and Holistic Planned Grazing offer an opportunity for students to learn about important food and fiber related topics from a perspective grounded in systems thinking. In summary, organizing a course around the Framework would combine the best of STEM education with the roots of SBAE where agricultural content was taught in an interdisciplinary manner before courses were separated into specific disciplines.

Figure 3

Available HM Resources

There are resources available for AFNR educators who want to start incorporating systems thinking into their courses through the integration of the Holistic Management Framework. There are 15 Savory Hubs in the United States conducting HM training which AFNR educators could complete. In addition to the Hubs, there are accredited HM Professional Educators who conduct HM training. Furthermore, there are course materials available that accompany these trainings. Savory's book Holistic Management 3rd Edition serves as the basis for these materials as well as courses. Finally, there are online courses available as well through the Savory Institute (http://savory.global).

Food and fiber systems are facing numerous grand challenges both in the United States as well as globally. These challenges are wicked problems involving complex systems. The agricultural professionals who will be addressing these challenges must be accomplished systems thinkers who are able to be part of interdisciplinary teams. The Holistic Management Framework is an effective approach for utilizing a systems approach when managing land and natural resources. AFNR educators should consider leveraging HM to incorporate systems thinking into their programs. The world needs systems thinkers capable of managing food and fiber systems holistically.

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THEME ARTICLE

Navigating Change: Practical Strategies to Promote Resilience in AFNR Education

by Catlin M. Pauley

As Seniors leave our Agriculture, Food, and Natural Resources (AFNR) programs, they may begin careers in AFNR systems, advance their education at a college, university, or trade school, or simply continue their roles as consumers. However, no matter the path our students take, it is no secret they are entering a complex and changing world in which they will be tasked with addressing the wicked problems of today and of the future.

To support our graduates in addressing wicked problems, we must teach students to see the world as complex, with interconnected social and ecological systems. To further their success, we must also highlight the ever-changing nature of these systems and prepare students with the ability to foster social-ecological resilience through their work.

Social-ecological resilience

Change in AFNR systems is always occurring. New technologies are developed, weather patterns change, and consumer preferences vary. Each change brings an impact which can strengthen, weaken, or even completely alter the system itself (Biggs, Schlüter, & Schoon, 2015). For example, a student's Supervised Agricultural Experience (SAE) may encounter change if her melon crop is destroyed by disease. If she has no other means of income, or the disease prevents her from growing melons next year, she will have to adapt her SAE to stay in the AFNR business or abandon the business altogether. The ability of a social-ecological system, such as the melon farm, to withstand change while still maintaining its identity (i.e., a fruit farm) is known as social-ecological resilience (Biggs, Schlüter et al., 2015).

Building social-ecological resilience through AFNR Education

AFNR teachers foster knowledge and skill development in many future agriculturalists who will be tasked with addressing current and future wicked problems, which makes AFNR education a prime hub to promote resilience thinking (Pauley, McKim, & Hodbod, 2019). Practical ideas to connect resilience-building principles (Biggs, Schlüter et al., 2015) to the curriculum and other activities in our AFNR programs are explained below.

Principle 1: Maintain diversity and redundancy

While maintaining both different (i.e., diverse) and similar (i.e., redundant) elements within AFNR systems may seem counterintuitive, both are valuable for building resilience (Kotschy, Biggs, Daw, Folke, & West, 2015). For example, a livestock and grain enterprise may be more resilient during a drought than a less diverse, grain-only farm. However, by increasing redundancy through a variety of grains, or even a variety of hybrids, the grain-only farm may also be able to curb the impact of the drought enough to remain resilient.

In AFNR programs, one way teachers can promote diversity and redundancy is by welcoming students with diverse backgrounds to join the conversation and action within AFNR systems. The differing perspectives could create a new learning experience for all students or create a discussion which could strengthen AFNR in the community.

Principle 2: Manage connectivity

AFNR teachers are often known for establishing connections between the program and the community. For building resilience, creating and managing these connections are essential. Establishing connections with local experts who can assist students with SAEs, career development events, or classroom projects can introduce students to new knowledge, ways of thinking, or opportunities which may strengthen their ability to act in AFNR systems. Additionally, connections with nearby AFNR programs or other community organizations can serve to identify additional opportunities for students to learn about and engage in AFNR systems.

Principle 3: Manage slow variables and feedbacks

The management of AFNR systems is often as complex as the systems themselves. However, managers typically focus on "fast" variables, such as feed quality, forest pests, commodity markets, and consumer preferences, which are more visible and respond quickly to interventions. Though changes to fast variables do impact the system, the "slow variables," or underlying factors which shape the structure of the system (e.g., climate change and soil degradation), are often left unmanaged (Biggs, Gordon, Raudsepp-Hearne, Schlüter, & Walker, 2015).

As AFNR teachers engage students in learning about and participating in AFNR systems, we should highlight the importance of both "fast" and "slow" variables. While focusing on fast variables provides quick results and often allows students to see the effects of their decisions, it neglects the core of the system and may only serve as a temporary fix for a long-term problem. Alternatively, AFNR programs can engage students in long-term management of a slow variable of importance to their communities. For example, students could explore the effects of mining on wildlife species diversity and populations or track and compare long-term climate data with the program's maple harvests.

Principle 4: Foster complex adaptive systems thinking

Complex adaptive systems thinking highlights the complex, dynamic, and interconnected nature of systems (Bohensky, Evans, Anderies, Biggs, & Fabricius, 2015). Incorporating discussions of the food system into the curriculum is a great way to foster complex adaptive systems thinking in the AFNR program. An exploration of connections between food and the environment, economy, society, government, and more allows students to see the interconnections and complexity of getting food from its origin to our plates. Further, teachers could use or ask students to create concept maps of the food system allowing students to visualize the connections and complexities.

Principle 5: Encourage learning

Of all the resilience principles, encourage learning may be the most sensibly connected principle to AFNR education. However, there is more to principle five than just learning about AFNR systems. AFNR teachers should encourage students to consider not only what we know about AFNR, but how we know it. Where does the knowledge come from and how do we know it to be true? Asking and answering these questions encourages students to connect people and society to the natural systems they are learning about.

Additionally, as AFNR systems are constantly changing, the importance of lifelong learning is crucial. Teaching students historical foundations and current best practices of agriculture is important to their futures in agricultural careers or as consumers. However, even more important is the ability of students to learn continuously, whether gaining new knowledge or revisiting prior knowledge, determining its applicability, and adapting or modifying their thinking.

Principle 6: Broaden participation

Broadening participation refers to involving people in management and decision making (Leitch, Cundill, Schultz, & Meek, 2015). Many opportunities to support this resilience-building principle exist within our AFNR programs. For example, supporting students to undertake an SAE which allows them to manage and make decisions in a school enterprise allows for more diverse knowledge in the project and builds confidence among students that they can succeed in AFNR systems and their decisions can create an impact.

Principle 7: Promote polycentric governance systems

Often, when people think of governance systems, formal government agencies come to mind. However, polycentric governance systems within resilience thinking refers to both formal and non-formal decision making and management bodies at varying scales (Schoon, Robards, Meek, & Galaz, 2015). The FFA, for example, is a polycentric governance system. Officer teams and boards of directors at local, state, and national levels manage the activities of the organization. As we consider building resilience through our AFNR programs, the FFA is an ideal avenue to support principal seven. Local programs can use connections with other nearby programs to collaborate on shared AFNR system projects. Programs could also seek support or resources from the state or national organization to further their work in AFNR and their communities.

Call to Action

In a constantly-changing world full of complexity, we, as AFNR teachers, have an amazing opportunity and responsibility not just to prepare our students for work in the existing AFNR systems, but to prepare them to adapt to changes and strengthen the resilience of AFNR. This preparation occurs in our programs and can be strengthened by implementing the practical strategies identified for each of the seven resilience-building principles into instruction, FFA, and SAEs.

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THEME ARTICLE

Are We Preparing Yesterday's Leaders?

by Adam Cletzer

In 1982, the futurist R. Buckminster Fuller estimated that, until 1900, all human knowledge doubled about every century. Today, in 2020, IBM estimates human knowledge doubles every 12 hours.

This is challenging because when we are presented with new knowledge, we are forced to change — and, as you're probably aware, change is hard. Whether it be change in the agriculture industry, change in your community, or change in broader society, the pace of change is becoming faster and more violent, and the problems are becoming more wicked.

Leaders and leadership are essential in solving wicked problems because leadership's evolutionary purpose, among other things, is to help groups change in order to solve problems.

How, then, do we prepare leaders who can grapple with the pace and scope of the change brought about by this knowledge tsunami? Leadership scholars think they have an answer, but, if you will pardon the irony, you're probably going to have to change.

In this article I will explain how leadership has evolved and the promise of new collectivistic and distributed forms of leadership for solving wicked problems. I will end by offering guiding questions for improving your leadership program.

Where We've Been

As the challenges we face have changed, we've always changed the way we work together to meet them. Recently, Dr. Simon Western described in his book, Leadership: A Critical Text, four discourses of leadership that have developed in the past 100 years and remain prevalent today.

Almost everyone has a dominant leadership discourse, including agriculture teachers. Your dominant discourse informs your personal understanding of leadership, but, often, it will unconsciously dictate what your FFA leadership program is like and how you prepare leaders. If we don't examine our thinking, we risk becoming trapped in a discourse. You could be preparing leaders for 1980.

Dr. Western dubbed the four discourses as follows: (a) leader as controller, (b) leader as therapist, (c) leader as messiah, and (d) leader as eco leader, referring to the primary role the leader plays in a group. I present them now in the order they developed in society; however, all are still present in our leadership programs.

Leader as Controller. In the early 1900s, during the Industrial Revolution, huge numbers of people left farms and rural life to work in urban factories. The assembly line, mechanization, and the factory hierarchy necessitated a whole new way of working together. During this time, we began to think of leaders as the people who knew the most efficient and productive way to accomplish a task. Followers tended to accept their role as a "cog in the machine" as necessary to getting things done, essentially just trading their time and labor for money.

A person who views leadership in this way will tend to value leaders who are efficient and productive — who make the trains run on time. They tend to expect rules, respect positional power, and are obedient for the sake of order.

This discourse still tends to dominate in sectors of society where there is a right way to do something (e.g., manufacturing) or where people might die (e.g., hospitals, the military).

The reason you might be looking on this discourse with some suspicion, however, is because of World War II, where we fought authoritarian leaders like Hitler (who was bad), and authoritarianism in general.

Leader as Therapist. Following WWII, a few things happened that changed the way we do leadership. First, we were understandably distrustful of authoritarian leaders big and small. Followers began demanding a greater share of decision-making power, and a greater share of authority. We democratized leadership.

Second, we all got wealthy. Since our basic needs were met, rather than trading our time and labor for money, we started going to work to find meaning and a sense of community. And we wanted leaders who would help us reach our full potential. For the first time, we selected and sustained leaders who valued the follower.

A person who views leadership in this way will value a close-by, caring leader who listens and supports in order to help his or her followers reach their full potential. These types of leaders believe happy workers are more productive workers; that people are the most important part of the organization; that there's no "I" in "team." This is also the moment when Myers-Briggs, 360-Degree Feedback, and True Colors became popular. The ubiquitous Servant Leadership theory came out of this discourse.

This discourse still dominates in people-centered sectors of society, like academia, nonprofits, and youth development.

The reason this feel-good approach faded, however, is that it wasn't scalable. The late 1970s saw the first truly global corporations. How can you be a close-by, caring leader who motivates a worker in the Singapore office when you will never meet them? You can't.

Leader as Messiah. In the 1980s, business leaders began to solve this problem in a paradoxical way. They were able to coax employees to bring their whole selves to work and be "bought in" (a new buzz word in this era) to the company, thereby harnessing their ideas and creativity, while also manipulating their behavior through the use of vision and culture control.

Today, having a vision is almost a prerequisite for becoming a leader, but this is the moment that expectation became widespread. Visions allow the worker in the Singapore office, who you will never meet, something to latch onto. They become motivated intrinsically because they internalize the vision.

This is also the moment that we began talking about culture. It was always understood organizations had culture, but in the 1980s we began believing we could shape it. The thinking goes, if the leader establishes or manipulates the culture, the followers who are bought in will perpetuate it and police themselves.

A person who views leadership in this way will value inspirational leaders who can articulate a clear vision. They will value charisma and a certain shininess. They will tend to believe in the idea that if we find the right leader, he will solve our problems.

This discourse is the dominant discourse in the Western world. Most people are searching for their messiah leader to inspire them with their vision, give their work meaning, and show them how to live through culture.

The reason this discourse is on the wane, however, is because of the very pace of change I described earlier. When you rely on an individual (or even a small elite group) to provide the vision, set the culture, and solve the problems, you create a bottleneck in your organization's ability to process new information and adapt. They just can't keep up with the pace of change.

Leader as Eco-Leader. Around the turn of the century, faced with the knowledge tsunami and increasingly interconnected, interdependent, and wicked problems, we began to see leadership evolve yet again.

To combat the bottleneck in processing power, we began to distribute leadership more broadly throughout the organization. We stopped seeing leadership as vested in position and more as a fluid role. We began to think of any individual as being both capable of, and responsible for, contributing to the leadership of the organization in some way. Distributed and collectivistic leadership theories came out of this discourse.

A person who views leadership in this way will value impacting the organization regardless of position. They will tend to believe that there's no way a small group of individuals could make all the decisions, and that it's their responsibility to contribute their skills, rather than waiting on directions to follow, or a vision to support.

Though messy, the benefit to this approach to leadership in today's world is that by distributing the power and responsibility for leadership to all actors in the organization, you utilize the talent, creativity, energy, and intelligence of the whole system, rather than an elite few or one charismatic leader. When done well, you get better decisions, greater satisfaction with the organization, and greater commitment.

What is Happening in Agriculture Education?

In the September/October 2019 edition of this magazine, Blaze Currie described "A Tale of Two Chapters" and their varying approaches to leadership. One chapter's leadership development focused exclusively on a "Golden Six," where the most talented and coachable six members were chosen to do the leadership for the organization. It was orderly, rigid, and award winning. The second had a different approach. Mr. Currie wrote, "I could not identify six chapter leaders because there were dozens…each seemed to lead a special project or initiative." It was messy, but leaderful.

The first chapter typifies leadership under a controller, therapist, or messiah discourse of leadership. The responsibility and expectation for leadership is concentrated in an elite group. The dangers of this are numerous. Students can come to equate leadership with position. They believe if they don't win a position, then they can't contribute to the leadership, thereby robbing the organization of their talent. If a member does win a position, the outcome can be worse. They're often taught to believe they must provide the leadership for the organization, that their role is most important, that they are most responsible for the success or failure of the organization, and that they alone must solve its problems. It not only sets them up for failure in that office, but also in the world.

The second chapter typifies an eco-leader (i.e., more distributed leadership) approach. The opportunities and expectations for contributing to leadership are distributed broadly among the members. Everyone seems to feel responsible for, and capable of, contributing to the leadership of the organization. This arrangement not only provides the officers an opportunity to lead in an environment more akin to a 21st century organization, it also models for all members what a leaderful organization could look like when they participate.

How to Improve Leadership Programs

Agricultural Education teachers can work to improve their leadership education programs by asking themselves a few fundamental questions.

How broadly are the opportunities for leadership distributed in your chapter?

Concentrating the responsibility for the leadership of a chapter in the hands of a few key individuals is problematic, as I've described prior. If FFA is to be the premier leadership development organization, shouldn't more than a select few members be able to contribute to the leadership of the chapter in some way? Often, these non-positional leadership opportunities happen on the sidelines, informally, and are not recognized as leadership by student or advisor.

Is there an educational plan for leadership opportunities that are not positional?

Does your leadership development plan focus entirely on people with a title? How would it change your leadership program if you spent the same time thinking through how leadership could be nurtured among those students who do not have titles?

Are there meaningful opportunities for change?

The work of real leaders is to help a group adapt in order to tackle problems. This means challenging and reestablishing values, priorities, organizational direction, mission, and culture so that the organization can meet its challenges. Where do we allow students to make meaningful changes in their chapters, or more broadly in their schools or communities?

In conclusion, I'm interested in exposing students to an approach to leadership that best equips them to face the problems we have today. That means recognizing that leadership isn't about having a position, knowing the right answer, or selling us a vision — it can't be; because one person can't possibly keep up with the pace of change. It must be about preparing students to bring as many people into the leadership process as feasible, and then harnessing their talents, creativity, and intelligence. The leadership needed today is what was happening in the second chapter Mr. Currie described. Those students are who will be best prepared to solve today's wicked problems.

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WICKED Decisions

by Taylor Ruth, Joy Rumble, Alexa Lamm and Jason Ellis

Climate change. Food security. Environmental sustainability. These are just a few of the WICKED, or complex problems, our agricultural students will have to address in the future. However, the complexity of these issues coupled with the ever-changing nature of society today has made it extremely difficult to decide how to best address these issues. Agricultural and scientific literacy has expanded beyond simple understanding, and now asks people to apply concepts and make decisions related to science and agriculture in our day-to-day lives.

To help prepare our students to have conversations about these WICKED problems and increase agricultural and scientific literacy, we need to first understand how people make decisions related to these complex topics.

Understanding Decisions

Back in 2017, my co-authors and I worked together to develop a new model for understanding decision-making in agriculture and natural resource (ANR) science technology. This model was based on past established theories (Noelle-Neumann, 1973; Petty, Brinol, & Priester, 2009; Rogers, 2003) and was published in the Journal of Agricultural Education. For the sake of brevity, we have boiled it down to the key elements you might find most helpful to discuss in your classes.

Our hope is you can use the information from our model of decision-making, along with the corresponding activities, to help your students understand how to best facilitate decision-making with people they may communicate with about ANR. The key elements to consider when informing decisions are the person, the innovation, the society, and the message.

The Person

One of the most crucial things to consider when understanding how people make decisions is that everyone is different. We cannot assume everyone comes from the same background, has the same values, has the same access to education, etc. Our experiences, knowledge, and beliefs often guide the decisions we make. Therefore, understanding who you are communicating to is the first step in understanding how they will make a decision.

Activity: Have students complete an audience analysis or create a "Facebook page" to help them understand the attitudes, values, demographics, etc. of the audience they are helping to make a decision.

The Innovation

When we say "innovation" we mean anything that is new to the person you just identified. For example, using cover crops to increase soil quality may be common knowledge to you but an innovation to someone in an urban area. These innovations can help address the WICKED problems you have been discussing in class. However, not all innovations are created equally, and you need to understand how your audience will respond to the innovation.

A few questions to ask are:

- How easily can your audience see others using the innovation?
- Is this innovation compatible with your audience's existing values and current behaviors?
- Will this innovation be too complex for your audience to understand or use?
- Does this innovation present any direct advantages for your audience?
- Can your audience try out this innovation on their own?

The simpler the innovation and the easier it is for your audience to try out, see, or implement, the greater chance it has for success.

Activity: After analyzing their audience, give students a specific innovation and have them answer the questions above for that audience. Ask students to outline the incentives and challenges associated with the audience choosing to use that innovation.

The Society

It would be great if we could make decisions in a vacuum and did not have to think about the social pressures associated with our choices, but this is not the case. People try to conform to the group because they do not want to feel isolated or be the odd one out. For example, I do not like Reese's Peanut Butter Cups – the idea of peanut butter and chocolate together makes my skin crawl. Yet I don't often voice this opinion in public because it is usually met with gasps of horror. I don't like that feeling, so I usually stay quiet on the issue.

This social pressure informs decisions related to WICKED problems too. People may choose to use reusable grocery bags or paper straws because they want to get rid of single-use plastics… or because they want society to view them as a "good person."

If people believe others feel a certain way toward an innovation or will feel that way in the future, they will start to conform their own attitude/behavior to match that societal expectation. Our students need to be aware of this to help them understand how social pressure can also influence decisions.

Activity: Ask your students to think of a time they did something or bought something due to peer pressure. Now have them consider the social or peer pressure associated with the audience and innovation they have been analyzing.

The Message

Once you have a good grasp on who is making the decision, what the innovation is, and what society might think about the innovation, we get to the fun part – messaging! Messages should be tailored to the audience and reflect their values and how they likely perceive the innovation.

One of my favorite examples of tailoring messages comes from when we were testing messages to promote Florida strawberries along the Northeastern seaboard of the United States. Florida strawberries are grown during the winter and are very much an "innovation" to northern states where the main option for produce during that time of the year were imported from other countries. In Florida, the message "Florida Strawberries – A Taste of Summer all Winter Long!" was a hit. However, consumers in Boston did not respond well to the message when they received it in the middle of a snowstorm. These people did not need to be reminded it was winter and wanted nothing to do with that message.

The messaging this audience preferred was "Florida, Fresh and Fabulous. In Season Now!" mostly because they were unaware of Florida's winter growing season. This message allowed the audience to see they were able to purchase Florida strawberries in the winter and provided advantage over purchasing imported fruit, which made the strawberries appealing to purchase.

While these messages about strawberries address the product itself, some messages may have to also address social pressures associated with the innovation. For example, "Be a good neighbor & turn off your sprinklers when it rains!" or "Join the thousands who have already donated to support farmers affected by flooding," could lead to behavioral changes that conform to the expectations of society.

These examples are just short snippets or messages you might see on billboards but could be expanded for educational campaigns, public relations materials, news stories and more. At the end of the day, the message just needs to resonate with the receiver to have an impact on their decisions.

Activity: Have students review their analysis of the audience, innovation, and society. Ask students to create 2-3 messages that would promote the innovation to the audience then read the messages back to the class. The rest of the class can put themselves in the shoes of the audience to provide feedback for the messaging. Does the message address the person, the innovation, and/or the society?

Moving Forward

People will continue to make ANR decisions with or without our input. However, if we can prepare the next generation of agriculturalists to communicate about WICKED problems and the innovations created to address them, people can make a more informed decision. The activities discussed in this article could easily be integrated into animal science, environmental science, horticultural science, crop science classes and more to help our students create a more agriculturally and scientifically literate society.

If you are curious to learn more about the model we created and read about the specific theories that guided this work, please check out our article:

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THEME ARTICLE

Preparation to Solve Wicked Problems Through Three-Dimensional Science Learning

by Craig Kohn

Introduction: Wicked problems that are seemingly resistant to solutions are widespread in the agriculture industry. In particular, the "2050 Challenge" of increasing food production by 25-70% with fewer resources in increasingly unpredictable environments is one of the most dramatic wicked problems humanity faces (Hunter, et al., 2017). Traditional forms of education that emphasize acquisition of rote facts and repetitive skills fail to adequately prepare students to address wicked problems in real-world settings (Yukawa, 2015).

The need to better prepare students to address socioscientific issues like food production was an impetus for the publication of the National Research Council's (2012) *Framework for K–12 Science Education* (or simply "the *Framework*"), which also serves as the basis for the Next Generation Science Standards (NGSS Lead States, 2013). The *Framework* stipulates that science learning should be three-dimensional, meaning that disciplinary core ideas, scientific and engineering practices and crosscutting concepts should be utilized as seamlessly interconnected components of science instruction.

Given that agricultural education generally entails large amounts of science and engineering content, the research-based findings of the *Framework* can inform the implementation of classroom-based instruction in agricultural education. In this article, I will briefly summarize the basics of three-dimensional science instruction as described in the *Framework*. I will then provide an example of a research-based curriculum called *Carbon TIME* that explicitly utilizes three-dimensional science learning, and conclude by addressing the implications for classroom-based agricultural education.

Overview of Three-Dimensional Science Learning: Much of the contemporary research literature about science learning is synthesized in the *Framework's* vision for three-dimensional science learning (Laverty, et al., 2016). The Framework describes these three dimensions in the following manner:

- Science and Engineering Practices: rather than merely simulating how scientists and engineers conduct their work, the Framework stipulates that students themselves should be engaged in the practices of scientists and engineers. The specific use of the term "practice" reflects the need for both knowledge and skill in scientific pursuits. Examples of Science and Engineering Practices include analyzing data, evidence-based argumentation, developing explanatory models, and evaluating information.
- Crosscutting Concepts: some key concepts shape our reasoning in many branches of science and engineering. These include identifying patterns, establishing cause and effect, and recognizing the conservation of energy and matter. These provide constraints to reasoning that guide scientists and engineers towards more valid conclusions and more viable solutions.
- Disciplinary Core Ideas: the amount of scientific knowledge is simply too extensive to successfully cover all of it in K-12 education. Furthermore, fact memorization has minimal utility in modern society. However, some understanding of scientific content is necessary to prepare students to make sense of the world throughout their lives. The Disciplinary Core Ideas reflect a very limited set of concepts with broad explanatory power that support productive reasoning and problem-solving.

The *Framework's* vision for science education reflects a shift beyond just investigating the natural world to enabling students to accurately reason about phenomena and develop viable solutions. One hallmark of three-dimensional learning is that more emphasis is placed on "figuring out" rather than "learning about." This means students engage in *sense-making* in which they must use both knowledge and practice to explain phenomena and design solutions. For example, while science students traditionally might *learn about* photosynthesis, three-dimensional science instruction engages students in *figuring out* how plants produce their own food through collaborative investigations and model development.

Carbon TIME: Michigan State University's *Carbon TIME (Carbon: Transformation In Matter & Energy)* research project is one example of a university-based research initiative that supports engaging students in three-dimensional science learning. *Carbon TIME* is a federally-funded research project consisting of scientists, teachers, and graduate students (including myself). The *Carbon TIME* curriculum consists of six modules for secondary students (freely available online at https://carbontime.bscs.org/). These materials focus on the processes that transform matter and energy in biological systems, including combustion, photosynthesis, cellular respiration, digestion, and biosynthesis.

The *Carbon TIME* materials provide curricular scaffolds that are necessary to effectively support student engagement in three-dimensional science learning. Each unit is organized into three segments, each of which incorporate disciplinary core ideas, science and engineering practices, and crosscutting concepts in an interwoven manner:

- Students as Questioners – each unit is designed around a driving question related to a specific phenomenon. Curricular scaffolds guide students in identifying additional supporting questions related to this phenomenon.
- Students as Investigators – initial unit discussions and lessons on foundational knowledge prepare students to investigate their questions. The curricular materials and teacher support guide students as they analyze data, identify patterns, develop explanatory models, and reach evidence-based conclusions.
- Students as Explainers – students conclude each unit by using molecular models to understand the phenomena at the atomic-molecular level and connect system models at different scales. Students are then guided in developing rigorous scientific explanations that address the driving question. They conclude by utilizing these explanations to address other related phenomena.

For example, the central driving question of the Plants Unit in *Carbon TIME* is: *How do plants grow, move, and function?* First, students assume the role of Questioners. They express and record their ideas about how plants grow and function before identifying specific questions to guide their learning. Students then assume the role of Investigators. They first learn a limited amount of core disciplinary content, such as plant structure and function at different scales. Students then plan and conduct investigations of growing radish plants. They measure how plant mass and CO_2 levels change for radishes in light or dark conditions. They identify patterns in their data analysis (for example, growing plants absorb CO_2 in the light and gain more mass than the soil loses). This enables students to engage in evidence-based argumentation leading to conclusions about plant growth (e.g. reductions to CO_2 are related to the gains in plant mass), as well as unanswered questions (e.g., what happens to the CO_2 that plants absorb?).

Finally, students take on the role of Explainers. They answer their questions by developing explanations that connect their observations with atomic-molecular models to the processes of photosynthesis, cellular respiration, and biosynthesis. Finally, students apply these explanatory models to examples of other plants that grow in different ways.

Research conducted through *Carbon TIME* has shown that this curriculum is much more effective than traditional fact-based science instruction (Anderson, et al., 2018). These materials can inform curriculum and instruction in agricultural education by providing a replicable model for three-dimensional science instruction. In particular, the final units of the curriculum, *Ecosystems and Human Energy Systems,* specifically address wicked problems related to agricultural and natural resources considerations from a systems-level perspective.

Implications for Agricultural Educators: To date, 44 states have adopted science standards guided by the *Framework's* recommendations (NSTA, 2019). Agricultural courses offered for science credit will need to provide three-dimensional learning in order to be aligned to most state standards. Even for teachers who do not teach for science credit, the *Framework* reflects the most up-to-date understanding of how students effectively learn science in a manner that results in meaningful changes such as more informed decision-making (Schwarz, et al., 2016). This is quite relevant to classroom-based agricultural education, as the primary purposes specified in its mission statement are to prepare students for both careers and informed choices in agriculture (FFA, 2019).

Findings from *Carbon TIME* research suggest that in order to effectively implement three-dimensional science instruction, teachers need a) curriculum that is fully NGSS-aligned, b) repeated professional development opportunities, and c) a support network of teachers and education researchers. While this is not immediately feasible for all agricultural instructors, there are smaller steps that can be taken in the meantime.

First, agricultural instructors can evaluate whether their own agriscience instruction is more predominantly "learning about" or "figuring out." Curricula that primarily emphasizes the memorization of facts is not three-dimensional even if it includes inquiry. This is an important distinction, as some agriscience curricula claim to be NGSS-aligned but fail to sufficiently incorporate three-dimensional learning. The NGSS Lesson Screener is a valuable tool for evaluating curricular options (https://www.nextgenscience.org/sites/default/files/NGSSScreeningTool-2.pdf).

Next, agriculture teachers should consider working closely with their science departments to learn more about the *Framework* and NGSS if they haven't already done so. Numerous opportunities for professional development are available, and the National Science Teachers Association has multiple publications to provide guidance to teachers (such as *Helping Students Make Sense of The World Using Next Generation Science and Engineering Practices*). Finally, teachers can actively request support from their state professional associations, land grant education faculty, and departments of education in guiding their implementation of three-dimensional science learning.

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THEME ARTICLE

Looking Back to Look Forward: SBAE in West Africa as a Clumsy Solution to a Wicked Problem

by Haley Traini

Recent Ponderings

Many philosophers, historians, and political leaders have warned humanity about the dangers of historical recurrence or the notion that history repeats itself. No doubt, you've heard this phrase before. And, like philosopher George Santayan said, "those who cannot remember the past are condemned to repeat it," these warnings are often said in a cautionary tone. But, is historical recurrence always a bad thing? Are there things we have done in the past that bear repeating? This is a question I've considered recently as I reflect on the notion of wicked problems and my work and research with AgriCorps, a non-governmental organization that seeks to alleviate hunger in West Africa by implementing a historical model, one that we implemented in the U.S. over 100 years ago.

But before we get there, let me set the context a bit. A few years ago, I had the pleasure of living in rural Ghana for one year as an AgriCorps Fellow. As a privileged (and let's face it, extremely naïve) middle-class American high school agriculture teacher, I experienced a significant bout of culture shock when I first arrived. And although I had done extensive preparation by way of reading and learning about the country and culture, the stark differences in how people lived in Ghana compared to the U.S. flabbergasted me. To give you a little taste of this, here is an excerpt of a blog I wrote when I first arrived:

…I expected the lack of running water and power, but I didn't realize how underdeveloped Ghana was until immersing myself into the culture. Simple tasks of everyday life are more akin to how my great grandparents lived during the dawn of the 20th century than 2015. Daily tasks are performed by hand, with little machinery and almost no electricity. Mornings are filled with chores and preparations for the day. Children walk half a mile or more to the nearest well to fetch water, then walk back with full buckets on their heads. Women hang or take down laundry from the lines and find some miraculous way to iron their husband's shirts. Morning meals often require hours of effort, vigorously grinding grains with a mortar and pestle to make porridge or fufua, chopping raw vegetables and fruits, frying chicken or goat meat, and boiling water. Morning bathes are done with a bucket and scoop…

After reading this, it will be no surprise to hear that sub-Saharan countries like Ghana face significant problems with food insecurity, unemployment, and poverty. Moreover, although countries like these have received millions of dollars in aid over the past several decades (certainly with some improvement), these problems persist. Ghana is considered a food-deficient country with agriculture serving as the basis of the economy, accounting for a little over half of employment (FOA, 2013). Nearly 57% of Ghana's 28 million people are living at or below the international poverty line of US $5.50 per day (World Bank, 2020). As a country relying largely on agricultural activities for their income, factors such as underdeveloped markets, extreme weather, nonexistent or inadequate agricultural infrastructure, and post-harvest losses create significant barriers for people to break through generational cycles of poverty.

Wicked Problems and Clumsy Solutions

The problem of food insecurity in Ghana is what many consider a wicked problem. Unlike tame problems that have a clear and scientific solution (e.g., how to fix a broken arm) or critical problems that require immediate action by an authority figure (e.g., how a political figure might respond to a terrorist threat), wicked problems are entirely different. They are complex, involve multiple people and systems, and have no clear solution. There is no clear cause and effect for wicked problems, and when you do try to solve them, additional problems often emerge. They are inherently political, novel, and complex (Grint, 2010).

Because wicked problems are so messy, and no solution exists, we must attend to them in imperfect or what scholar Kieth Grint calls "clumsy" ways. To do this, we must stitch together inelegant "solutions" using whatever tools and resources we have at hand. This means that in places like Ghana, it's not a matter of simply giving people what they need (e.g., cash, a well and water pump in their community, drought-resistant seed), we must consider the wickedness of the problem and offer clumsy solutions that take into account the entire system and the people in it.

In 2009, former National FFA Officer Trent McKnight sought to address wicked problems in West Africa by founding AgriCorps. His ideas were both old and new. They were old in the sense that he planned to adopt, modify, and implement a model that was successful in the U.S. over 100 years ago. They were new in the sense that his ideas did not plan to assist West Africans through a traditional aid model. In fact, no money or physical resources would pass from AgriCorps' hands to those served abroad. Of course, many of you by now may know that this model is one we all cherish: 4-H, FFA, and School-Based Agricultural Education (SBAE)! Recall that at the dawn of the 20th century, agricultural researchers found adult farmers were reluctant to adopt new agricultural innovations and technologies developed at universities. However, young people were open to new ways of thinking and were more likely to experiment with new ideas and share those with their parents. Because of this, the first youth 4-H clubs were created to diffuse new agricultural innovations from the youth to adults through these clubs. As 4-H clubs spread in popularity across the country, and agriculture classes were offered in public schools (which gave rise to FFA), we saw how youth involvement in agriculture not only offered a positive way to teach youth new knowledge and skills but served as a mechanism to influence adults around them to adopt new and improved agricultural technologies.

Like 4-H clubs sought to aid American farmers in the early 1900s, so too does AgriCorps seek to diffuse agricultural innovations and technologies through youth programs, namely by strategically embedding 4-H programs in existing middle schools (4-H in West Africa acts much like FFA does in the US by pairing a club with the local school and agriculture teacher). And, although AgriCorps is still a new organization, there is evidence to show that this is a promising clumsy solution. I'll share two quick examples.

Lincoln's Cassava. Looking at the dismal yield of his father's cassava crop in rural Liberia gave Lincoln Dolo an idea. "Dad, we should plant the cassava sticks in a mound rather than straight into the ground." While his father was skeptical, Lincoln knew this improved method would increase yields because he had seen it work on the school farm. His father tried a few mounds and when harvest time came, he reaped the benefits, "it came up very fine. One stick in the mound gives 14, 15, 16 tubers when the old way gives 8, 9, 10 tubers."

One Seed per Hole. "The youth taught us!" exclaimed a group of older farmers explaining how they doubled corn yields in just three years. 4-H member Joseph Quarshie and Ishmael Domety, with their Ag Teacher Emmanuel Dugbatey, spent the last four years taking what they learned on the school farm into the community to help farmers. Quarshie worked with farmers on the "4-H method" of planting corn: one seed per hole with correct spacing and Ishmael taught conservation practices, terracing and composting during farm visits.

Food for Thought

At this point you may be asking, what does all of this have to do with me as a high school agriculture teacher? I share this with you because I'd argue that perhaps the notion of history repeating itself isn't always a bad thing. Might we learn about what has worked in the past to offer clumsy solutions to wicked problems we face in 2020? As we present wicked problems in our curriculum, how might we engage our students so as to get them to think critically about these issues? Perhaps we can have them look back to look forward? As we present information about wicked problems like global poverty, food insecurity, and climate change in our classrooms, might we challenge our students to engage in some retroactive research as a means to propel their thinking forward in developing clumsy solutions? Who knows, it may be a pretty cool learning experience!

Have questions or want to connect about this further? Please email me so we can start a conversation at haley.traini@oregonstate.edu.

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THEME ARTICLE

Using CASE to Better Understand Wicked Problems

by Melanie Bloom

Since 2007, the Curriculum for Agricultural Science Education (CASE) initiative has developed and used a unique curricular model to develop learners' abilities related to addressing complex problems. Before the term "wicked problem" came into public lexicon, CASE professional development goals included providing toolboxes for teachers to improve student awareness related to science-based agriculture, food, and natural resources and to improve student inquiry and problem-solving skills. By practicing problem-solving in controlled environments with instructor support, students develop the critical thinking and problem-solving skills to apply to more complex, wicked problems.

Many teachers, including school-based agricultural education instructors, might struggle to design and implement inquiry curriculum without examples, supports, and resources. CASE alleviates the design issue, providing 11 complete courses for teachers to implement as appropriate in their own program and district. Courses are carefully and intentionally crafted to scaffold learning throughout a sequence of student tasks, lessons, units, and courses.

CASE contractors carefully design curricula around industry-identified needs through the unique course development process. Of the twelve CASE Major Concepts used to frame each course, five seem pertinent to this conversation; they are highlighted below with a discussion around how each contributes to the handling of real-life problems through CASE courses. Each course also contains connections to FFA and SAE for All related to the specific course content. Other tools that help teachers implement CASE are purchasing manuals for each course, evaluation documents such as specific rubrics and answer keys for each student task, and lesson-planning tools and suggestions.

Professional development by CASE provides rigorous, hands-on practice through events specifically designed to enhance the curricular resources and content for each course. More than 70 of the best

CASE-certified inservice school-based agricultural educators, who meet rigorous standards, are prepared to facilitate CASE institutes every year. These Master and Lead Teachers work to provide between 40-90 hours of perspectives of the curriculum related to student and teacher needs. These PD experiences focus on facilitation of student tasks, lab set-up, evaluation and grading, lesson-planning, classroom organization and procedures, incorporating local agricultural connections, and purchasing.

What CASE does not provide is all of the classroom magic (read Make Learning Magical by Tisha Richmond), the teacher-student relationship, nor the direct connections to localized agriculture. Critical to student success, the local teacher is a critical component in the success of CASE implementation. He or she must find ways to help students connect agricultural science principles to everyday life. He or she also drives the discussion in the classroom. Throughout this article, you'll find a variety of examples where CASE teachers find ways to connect agricultural science to wicked problems as well as to local agriculture.

Ag is a science that contributes to the development, improvement, and sustainability of living things.

CASE course-long problems, obviously smaller in scale than wicked problems, offer opportunities for students to practice critical thinking skills and research processes. Different processes are used to investigate different types of problems or different facets of wicked problems. Academic research processes to understand the problem, scientific research processes to test practices related to the problem, the food product development process, engineering process to design components, and business planning processes all offer opportunities for students to mitigate problems in a real-life setting.

Throughout all CASE courses, students identify gaps, problems, issues, and opportunities related to specific content through the cumulative, course-long problems. Using skills and knowledge gained throughout each course, students conduct research to better understand the course content, then propose solutions and practices to mitigate a problem they identify independently.

Consideration of the ethical, environmental, social, and economic impacts of ag practices is essential to being a responsible, involved citizen.

All CASE courses are aligned to national Agriculture, Food, and Natural Resources (AFNR) standards, as well as the Next Generation Science Standards, the Common Core English Language Arts, and Common Core Math standards. Through course wide alignments to national standards, all CASE courses address one Career Ready Practice (CRP) and two AFNR Career Cluster (AFNRCC) standards that are directly related to wicked problems. Those standards read as follow. CRP #1 "Act as a responsible and contributing citizen and employee." AFNRCC #2 "Evaluate the nature and scope of the AFNR Career Cluster and the role AFNR play in society and the economy." AFNRCC #6 "Analyze the interaction among AFNR systems in the production, processing, and management of food, fiber, and fuel and the sustainable use of natural resources." Specific student tasks for each CASE course address these three, and dozens of other standards, in unique, engaging, and effective ways.

As students experience the three-ring model of agricultural education, they should take part in rigorous curricular experiences, quality FFA events and programming, and complete a Supervised Agricultural Education (SAE) program. The new SAE for All guidelines developed by the National Council for Agricultural Education provide great resources for traditional completer students as well as those "drop-in" students who might only be in your classroom for a single unit of instruction. CASE is working to incorporate all Foundational and Immersion SAE connections into each course. Beginning in 2020, CASE course revisions include even more FFA and SAE connections focused on improving student leadership, citizenship, and membership qualities.

Inquiry activities are important in the practice of scientific processes and in the world of research.

CASE courses employ three types of student tasks that vary by level of inquiry and critical thinking, according to Dagget's 2005 Rigor/Relevance framework. Activity, project, and problem (APP) designations helps teachers and students understand how to approach each student task.

Activities use a structured inquiry approach, meaning the whole group of students should arrive at predetermined outcomes that can be applied across disciplines. Knowledge and skills gained during completion of activities are spiraled throughout the course and sequence of courses. Analysis questions found in activities help students critically evaluate their learning and connections to agriculture and everyday life.

Projects, utilizing guided inquiry, result in predictable but variable outcomes through different student paths and discoveries. Projects apply to real-world or predictable, simulated situations. Students synthesize knowledge and create something new with what they have learned. All projects come with evaluation rubrics which facilitate critical discussion and feedback between teachers and students.

Open-inquiry **problems** remove the cap from student learning and result in very different processes, outcomes, and learnings. Applied to real-world, unpredictable situations, problems require students to identify needs, establish goals and constraints, seek knowledge via research, synthesize new knowledge, tackle project management issues, take risks, work with others, develop student understanding, and reinforce critical thinking skills needed in future careers.

Cumulative projects for the more advanced CASE courses include biotechnology research in Animal and Plant Biotechnology (APB), new food product development and marketing in Food Science and Safety (FSS), environmental issues analysis in Environmental Science Issues (ESI), and new agricultural equipment design to improve production or processing in Mechanical Systems in Agriculture (MSA). The newest CASE course, Agricultural Business Foundations (ABF) includes a semester-long business plan development process meant to meet some need within the community using business acumen and social sciences.

Effective interpersonal communication skills facilitate group processes and aid in solving complex problems and the achievement of common goals.

The CASE Introduction to Agriculture, Food, and Natural Resources (AFNR) course includes *Project 2.2.3 Teaming Up*, focused on group norming and teamwork skills. These student-developed group norms and teamwork skills should be referenced and used throughout the rest of the course as well as all other CASE courses that follow AFNR in sequence. CASE-certified teachers who use the Environmental Science Issues (ESI) course know that *Activity 1.2.3 Walk the Talk* results in classroom conflict guidelines for civil discourse about hot-button issues in environmental science. All courses include collaborative activities, projects, and problems. Transferring those communication skills allows for better communication about problems and discussions.

The Intro to AFNR course accumulates into *Project 7.1.1 Solving World Hunger*, which is also a great segue for teachers wanting to involve students in the World Food Prize Youth Symposium.

Critical thinking involves using a variety of problem-solving techniques in real-life contexts.

CASE-certified teachers find unique and creative ways to connect activities, projects, and problems to local, regional, state, national, and international agriculture. Effective interest approaches which help teachers and students connect broader agricultural science principles to everyday agriculture are often discussed and shared during CASE Institutes. APP extensions also help students see how knowledge and skills gained from activities can be transferred across disciplines.

A great example of this was shared by Jacob Hunter at North Scott CSD in Iowa from his Food Science and Safety class (FSS): "…in *[Activity 2.1.1 Sticky Starches]*, we used extra starches to add a global perspective, i.e. teff and amaranth. We then link it to biofortification/nutrient/food availability across the globe based on staple crops, specifically East Africa."

Jennifer Phelps, a Master Teacher from Carthage CSD in New York, regularly teaches the Natural Resources and Ecology (NRE) course. She offered the following connections as examples: *Lesson 2.2 Soils and Land* - Making decisions about land use on a farm. *Lesson 3.2 Water Function* - Monitoring riparian zones on farms implications for decisions related to fertilizer use, feed lot locations, etc, using the Water Quality Index. Lesson 9.1 Policing Our Wilderness - challenges related to protected species that may be living on or near agricultural land, such as wolves in the western U.S. Lesson 7.3 Digging and Drilling and Lesson 8.1 Urban Sprawl – APPs related to fracking and the energy trading activity connect to implications of climate change and the political, social & economic factors that influence our energy choices on and off the farm.

In Closing

Something new that the CASE team is excited about is an upcoming middle school curriculum, partially sponsored by Corteva Agriscience. The AgXplore (AgX) curriculum is designed around understanding the complexity of wicked problems and how agricultural sciences can be applied to understanding wicked problems better.

After 12-years as an agricultural education instructor in northwest Iowa, Melanie Bloom has worked as part of the CASE team as an independent curriculum contractor for the past six years and is also a PhD student at the University of Missouri-Columbia.


CASE