Authentic Science

Highlights from the Field

Exploring the NGSS Crosscutting Concepts through the work of Dr. Adina Howe and her team at Iowa State University

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A very special "thank you" to the entire Howe Lab team for devoting their time, expertise, and energy to this innovative project. Biotech Outreach is honored to showcase their outstanding research and thoughtful personnel.

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Photo by Tom Fisk from Pexels

I am an assistant professor in the Department of Agricultural and Biosystems Engineering at Iowa State University. I lead the Genomics and Environmental Research in Microbial Systems (GERMS) Laboratory. The goal of the GERMS Lab (www.germslab.org) is to understand and manage the impacts of microbiology as we continuously change the environment that we live in.

Our research provides data that is needed to inform our decisions and policy by developing innovative scientific methods that detect and quantify microbial activity in the environment. Our broad interests include the production, resilience, and safety of food, energy, and water resources; the impacts of land management strategies; the connection of environmental and animal microbiomes; and the large-scale detection of biomarkers for environmental health. Our past and present research includes identifying microbial drivers of biogeochemical cycling and their response to climate change; understanding contributions of microbial genes, individuals, and groups to population function and dynamics; detection of antibiotic genes and pathogen biomarkers; scalability of increasingly large sequencing datasets through the application of advanced computational approaches; and leveraging high throughput, next-generation metagenomic and metatranscriptomic sequencing to investigate interactions within environmental microbial communities.

I am also a part of Iowa State University's Environmental Science Program, Interdepartmental Microbiology Program, and Bioinformatics and Computational Biology Program. The GERMS Lab is currently supported by Iowa State University; the USDA National Institute of Food and Agriculture; the National Science Foundation; the Environmental Protection Agency; and the U.S. Department of Energy, Office of Biological and Environmental Research.

~ Dr. Adina Howe

www.abe.iastate.edu/adina-howe/

Adina Speaks: Equity at Work

Mentoring & Support

I am committed to producing trainees and scholarships that promote equity in science and decision-making. There are many challenging pressures that disproportionately impact varying students of varying backgrounds. I am thoughtful of these barriers in the mentorship and support that I provide my students and staff. Our research also serves diverse stakeholders, and we strive to provide communications that are accessible to not only our scientific peers but also the general public.

Women in STEM

It took me a long time to acknowledge that women in STEM face a set of different challenges. I find this odd now since my mother raised my sister and me by herself and had to also develop her own career while doing so. I think finding a balance in career, family, and personal goals is very difficult to achieve, and I'm still working on navigating these complexities. I find that having great mentors and a support system are really important to me.

Opportunities for All

I think it's really important for students to develop a strong work ethic, important work can rarely be done quickly and the ability to keep working hard to complete a goal is critical. These are skills that can't be taught. Understanding your own resiliency and keeping a growth mindset in challenging situations will help you be successful regardless of your careers.

Questions & Answers

What's your name and main area of research?

My name is Adina Howe and I am an assistant professor and researcher in the Department of Agricultural and Biosystems Engineering (ABE). My main areas of research include studying land and water resources and environmental microbiomes.

What brought you to Iowa State University?

I am a strong believer of the land grant mission to serve in teaching, research, and extension. The ABE department at Iowa State is also a wonderful group of faculty that truly care about this mission, their students, and our neighbors.

How many people work with you in the Howe lab?

The GERMS team is pretty big. We work with two research scientists, three post doctoral scholars, four undergraduate students, and four graduate students.

Where is your lab located on campus?

Our lab space is located in Sukup Hall and we also have office space in adjoining Elings Hall. Both Sukup and Elings are part of the Biorenewables Complex on Iowa State's campus.

What is it about research that keeps you interested in your work?

I am fascinated by the roles that microbes play in our lives – even though they are invisible, they provide such a wide variety of services in our lives, ranging from keeping our bodies healthy, helping our crops grow, and helping provide water quality to the environment.

Do you recall any K-12 teachers who impacted you and your decision to go into science/research?

I had wonderful teachers, and even if I can't specifically remember them, I know they played a positive role in my education and development. My chemistry teacher, Mr. Guy, my math teacher, Mr. Klumpe, and my English teachers, Mrs. Helton and Mrs. Gedney, are memorable. They taught me the value of hard work, self confidence, and to enjoy their subjects.

Photo by Anna Shvets from Pexels.com

What qualities or characteristics make a good researcher?

Great research doesn't have a clear cut answer. This requires curiosity to solve a problem or understand complexity, and persistence when the answers are not always easy to find. Our research also requires that you enjoy working with a team, you can't be an expert in everything and you need to rely on and enjoy the contributions of others.

The next few pages feature two of your researchers, Laura Alt and Grace Carey. What do you most value about their contributions to your research/lab?

Grace is an immensely positive personality. She works very hard and is very curious about microbiology. I find it difficult to imagine a day when I haven't seen Grace try to find a positive perspective. Laura is very dependable. I can count on Laura to handle any task I give her, and she does so with great independence.

Both Grace and Laura contribute great attitudes in our research program. They are quick to volunteer to help and communicate well with me and other team members. I really value that they both come to work and enjoy what they do and are grateful for being here.

Student Spotlight: Laura Alt & Grace Carey

What are your main areas of research?

I study how microbes interact with plants and with each other. My current project looks at how bacteria and genes from manure influence the bacteria that live in plant roots. (GC)

I conduct research to understand the impacts of agricultural management and practices on environmental quality. During my time as a graduate student, my work specifically focused on characterizing and quantifying the effects of prairie buffer strips on the fate and transport of antibiotic resistance contaminants (antibiotics, antibiotic resistant bacteria, and antibiotic resistance genes) in surface runoff and drainage water in agricultural watersheds. (LA)

Why do you like being a researcher?

I love discovering which facts are real and which are false. It's like being a detective tracking down tiny microbial criminals. (GC)

I genuinely love learning, and as a researcher you essentially become a lifelong learner. I constantly get to learn new skills and I'm always kept on my toes with how I expect my results to turn out and how they actually turn out. (LA)

Why did you choose Iowa State University?

I love farms and agriculture. When I was applying to graduate school I knew that I wanted to study microbiology under people who would teach me to use microbiology to make agriculture better. Iowa State is the perfect fit for me and I've never regretted coming here. (GC)

I was born and raised in Nevada, Iowa, so not very far from ISU. I've always tended to gravitate a bit toward science and research in the context of maintaining healthy environmental systems. When I decided to go back to school to pursue a graduate degree I saw a unique opportunity in applying to Iowa State. I could be in my home state interacting with a culture, topics, and environmental issues that I'd previously known about/ been familiar with and actually work to have an impact on things that may have directly impacted me while growing up. It also didn't hurt that I could stay close to family and that I ended up finding advisors who provided amazing mentorship along the way. (LA)

What keeps you motivated to “do science” when things get tough?

I am trying to find a solution for part of a real-world problem. I believe that everyone is responsible for solving problems and making the world better than they found it. Sometimes this isn’t easy, but it is always worth it. This keeps me motivated. (GC)

I have to constantly remind myself that progress in science is usually a game of incremental movement. Although we typically only hear about the outstanding breakthroughs of individuals or small teams, those breakthroughs are really coming on the heels of the tedious and incremental progress that came before them. It can be easy to get bogged down by our own personal struggles or our own personal tedious progress, but I like to keep in mind that everything I do helps provide a sturdier basis for scientific breakthroughs in the future! (LA)

What advice do you have for girls who are aspiring scientists and engineers?

Don’t assume that scientists or engineers are smarter or better than you. Science is more about hard work and persistence than about raw intelligence. If you’re passionate about studying a subject, if you want to test problems and find solutions to discover the truth, if you can work hard even when things are against you, and if you aren’t afraid of failure- you can be a scientist! (GC)

Persistence. Although it’s important to have hard skills in subjects like math, science, and communication, most of those skills can be taught or perfected through practice. More often than not the greatest challenges I face while doing scientific research aren’t that I can’t solve an equation or write a paper, they’re seeing results that I can’t make sense of or getting rejected from a journal or receiving criticisms that can feel pretty personal. As girls/women in an often male dominated field we really have to carve out space for ourselves and refuse to let people tell us where we belong and what we can or can’t do. Unfortunately, a lot of the time this may mean facing a lot of rejection and just repeatedly trying again and again until you find success. (LA)

The NGSS Crosscutting Concepts

Patterns

Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.

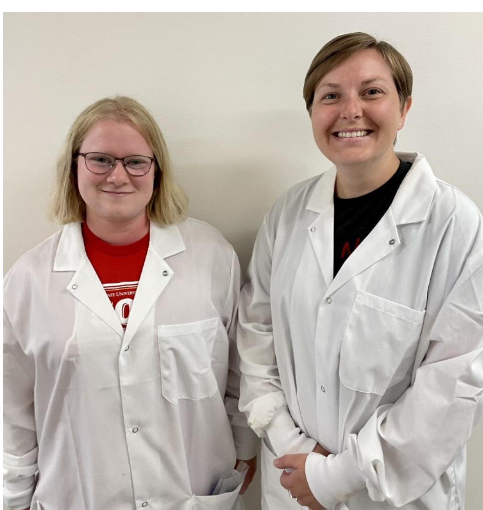
Cause and Effect

Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.

Scale, Proportion, and Quantity

In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change.

CCC descriptions from ngss.nsta.org/CrosscuttingConceptsFull.aspx



Questions & Answers

with Grace & Laura

What patterns do you notice in your work? How does recognizing patterns lead to discoveries?

Doctors rely on antibiotics to treat serious illnesses or minor infections. However, bacteria can become resistant to antibiotics. These resistant bacteria can be carried by manure and spread into the environment, where they may endanger human and animal health. In our work, we track these harmful polluting bacteria and their antimicrobial resistance genes (ARGs) in and around plant roots. We're looking for patterns of increasing resistant bacteria and ARGs after manure is added to soil and their potential pathway into our plants (food). These patterns may help us discover risk factors for antimicrobial resistance contamination in the environment.

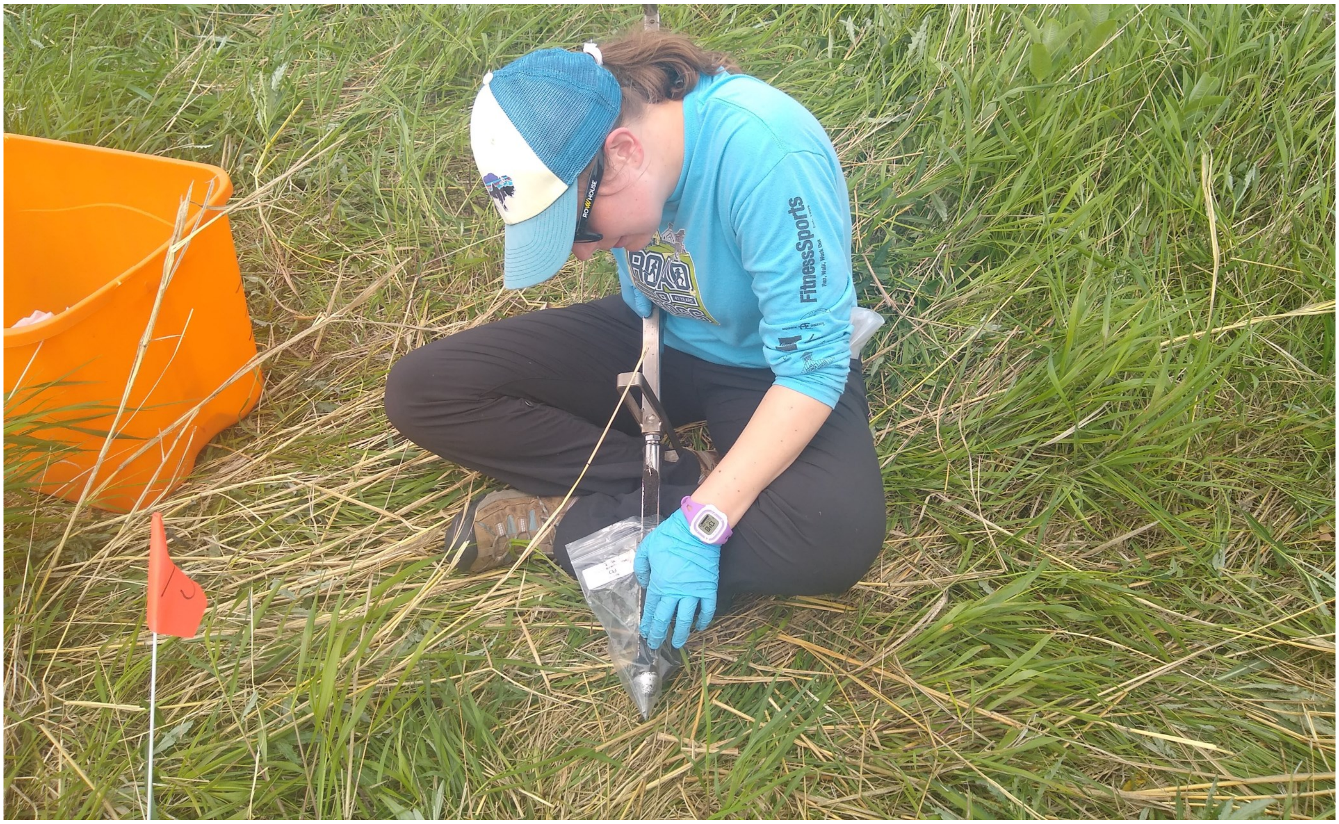
Our research has grown from previous research, done by our team and also done by others. Most research questions are formed from looking at previous research and making assumptions about what we expect to see. Others have previously seen that the use of vegetative filter strips could slow water movement from agricultural fields, resulting in cleaner soils and waters. Because there was evidence supporting the use of vegetative filter strips to remove these other contaminants, it was therefore proposed that prairie strips, a form of vegetative filter strip, might be able to remove antibiotic resistance contaminants.

Consider a time when you made a prediction based on patterns you've seen in your work. How did you test this prediction?

When manure is applied to a field, we find increased antimicrobial resistance genes and antimicrobial resistant bacteria in runoff coming from that field. Prairie strips grow plants with deep root systems that can 'filter' runoff at the edge of the field. In one of our projects, we hypothesized that planting prairie strips next to the field could reduce the presence of these contaminants in the runoff.

To test this hypothesis, we compared three different plots: a plot with manure application and a prairie strip, a plot with manure application and no prairie strip, and a plot with no manure application and a prairie strip. We then collected simulated rainfall on the plots and compared contaminants in the runoff of each plot.

In the end, the results supported our hypothesis. Runoff contamination was reduced in the manured plot with a prairie strip, compared to the plot without the prairie strip.



In your work, are there things that change consistently over time? How do you "track" these changes?

After a field is treated with manure, we track where the manure bacteria travel to over time. We can track the movement of the bacteria by extracting DNA from soil in different locations. The DNA is a fingerprint that can help us identify the microbes and genes at each location and see if the manure bacteria and antimicrobial resistance genes are present in new locations over time. We look for manure-like fingerprints after manure application to see where these bacteria end up.

What role does recognizing patterns play in data analysis?

Data analysis is really about telling a story with the information that you've collected. We try to go into data analysis with a hypothesis of what we expect to see based on previous observations/ patterns. Often, our results support our original hypothesis, but sometimes we are wrong and we'll make adjustments on our expectations for the next research project.

It's also important to set out with a planned data analysis in mind so that you don't bias your analysis toward what you originally expect to see.

What are some of the most common cause-and-effect relationships you see in your research?

We find that adding manure to soil causes soil microbial communities to change. It also increases the number of antimicrobial resistance genes in the area. We also find that planting a prairie strip next to a field can reduce soil and nutrient runoff and surface water pollution.

Give an example of a time when a small change had a big effect on something.

Our lab once did an experiment examining antibiotic resistance in soil sampled from a field. One section of this field was more sloped than the rest. This small change resulted in very different levels of our measurements, in this case bacteria and genes that may be risky to humans. Factors like these must constantly be taken into account when studying environmental systems. If you do not record these details, you may be surprised and confused by your experimental results after a lot of hard work.

How do you verify cause-and-effect relationships in your work?

When studying cause-and-effect relationships, we use negative and positive controls in our research. A negative control shows you what you would expect your sample to look like without any changes. A positive control shows you what you expect your sample to look like after an input. By comparing your treated sample with the negative and positive control, you may discover which changes in your sample were caused by your input.

When you analyze causes of failure in a system, how might you model the failure in order to determine a cause/solution?

Our systems do fail sometimes. For example, we once designed a system to test prairie strips' ability to remove contaminants from runoff water. During the design process, we diluted manure in a saline (or salty) solution and plated it to check for different contaminants.

During our actual experiment we repeated the dilution and plating process at a larger scale (much larger volume), however we saw much lower bacterial concentrations than we expected.

What happened? To find the problem, we double checked our calculations and, along with other team members, looked at every detail of our experimental process. Eventually, a team member pointed out that, while the design process used a saline solution to dilute manure, the experimental process used water. This small change caused the system we designed to fail. The bacteria had a much higher rate of survival in the saline solution as it represented a similar environment to the manure they had been previously living in. Therefore there was a factor we had not originally accounted for and our original design was incorrect.

To discover our failure and find a solution, we had to keep detailed notes of all the steps we took along the way. We checked that our failure wasn't the result of a calculation error, systematically compared the steps taken at each phase, and asked for a pair of fresh eyes to check for differences in our protocols.

Photo by Mark Stebnicki on Pexels.com

You use models frequently in your research. How do you decide at which scale something should be studied? (bench-scale. pilot scale, or full scale)

Our ability to scale our research and models depends on the questions we are asking and the available resources and funding. Bench scale (in the lab) experiments can help control for environmental variables that would be unmanageable at the field scale. But at the same time, those tightly controlled bench experiments may not produce results that can be repeated in the field.

In environmental microbiology, the scale and location of an experiment can strongly affect the experiment's findings. Therefore, we may begin with small-scale bench work to gather background information before moving on to field data collection.

Was there a time when changing the scale at which you studied something made a difference in your thinking?

Large-scale projects involving environmental samples come with a host of variables that must be teased out before making a conclusion. Scaling up a project, especially from a controlled lab environment into a field experiment, often will change conclusions. An example relevant to the prairie strip project involves a microcosm experiment in which soil samples from crop fields and prairie strips that received a treatment of manure application were incubated in jars and monitored over time. We intended to see how quickly antimicrobial resistance genes dissipated within the soils after manure application and whether we needed to be concerned with these genes' accumulation in soils. We saw that the targeted genes dissipated fairly quickly and found that accumulation might not be a problem. However, in looking at previous studies that have monitored resistance gene accumulation in manured soils at the field scale, we often see the opposite, that repeated manure application causes resistance genes to accumulate in soil over time. The differences seen in our results might have been influenced by the fact that we kept temperature and moisture consistent and controlled in our incubated soil samples. While controlling for these variables meant that we could compare manure's effect on our soil source (crop field vs. prairie strip), it also meant that our results might not be fully scalable to the field.


Photo by Johannes Strötker

Highlighted Resources for the Classroom

Visible research project
The Visible Research Project (VRP) is a collection of tools to help educators and researchers collaboratively design high quality student-facing curriculum materials which use authentic research projects to support students' science learning.
https://hallscience.us/visible-research

From Here to There with Woodchip Bioreactors
A high quality curriculum for use in 6-12 grade science classrooms based on the woodchip bioreactor work being done by Dr. Soupir.
https://www.oercommons.org/courseware/lesson/71904

What Can We Do? Antimicrobial Resistance in Agriculture and Beyond
Curriculum materials for use in 9-12 grade science classrooms focusing on the antimicrobial resistance (AMR) research being done in Dr. Soupir's lab.
https://www.oercommons.org/courseware/lesson/71017

NGSS@NSTA CCC full listing
One of the best, most simple online listings of the NGSS Crosscutting Concepts K-12 progressions.
https://ngss.nsta.org/crosscuttingconceptsfull.aspx

The NSTA Atlas of the Three Dimensions
A user-friendly guide for teachers to better understand how ideas (SEPs, DCIs, and CCCs) build on one another and relate to each other.
https://my.nsta.org/resource/117948

STEM Teaching Tools Brief #41: Prompts for Integrating Crosscutting Concepts into Assessment and Instruction
One of many STEM Teaching Tool briefs which provides practical examples of assessment prompts for classroom use.
https://stemteachingtools.org/brief/41

STEM Teaching Tools Brief #75: Using the crosscutting concepts to reflect on and refine your teaching. *One of many STEM Teaching Tool briefs which focuses on the use of crosscutting concepts to engage students in meaningful reflection as part of their learning.*
https://stemteachingtools.org/brief/75

More NGSS Crosscutting Concepts

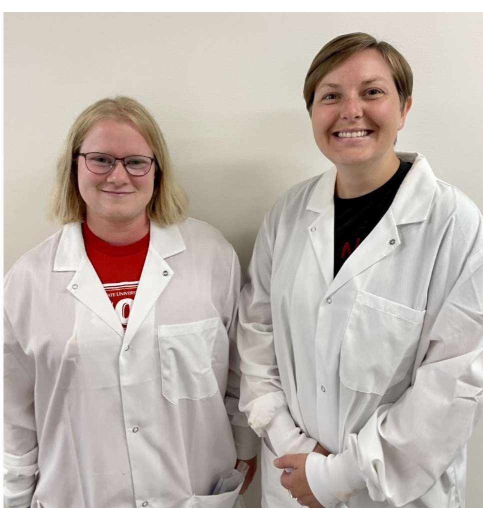
Systems and System Models

A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.

Energy and Matter

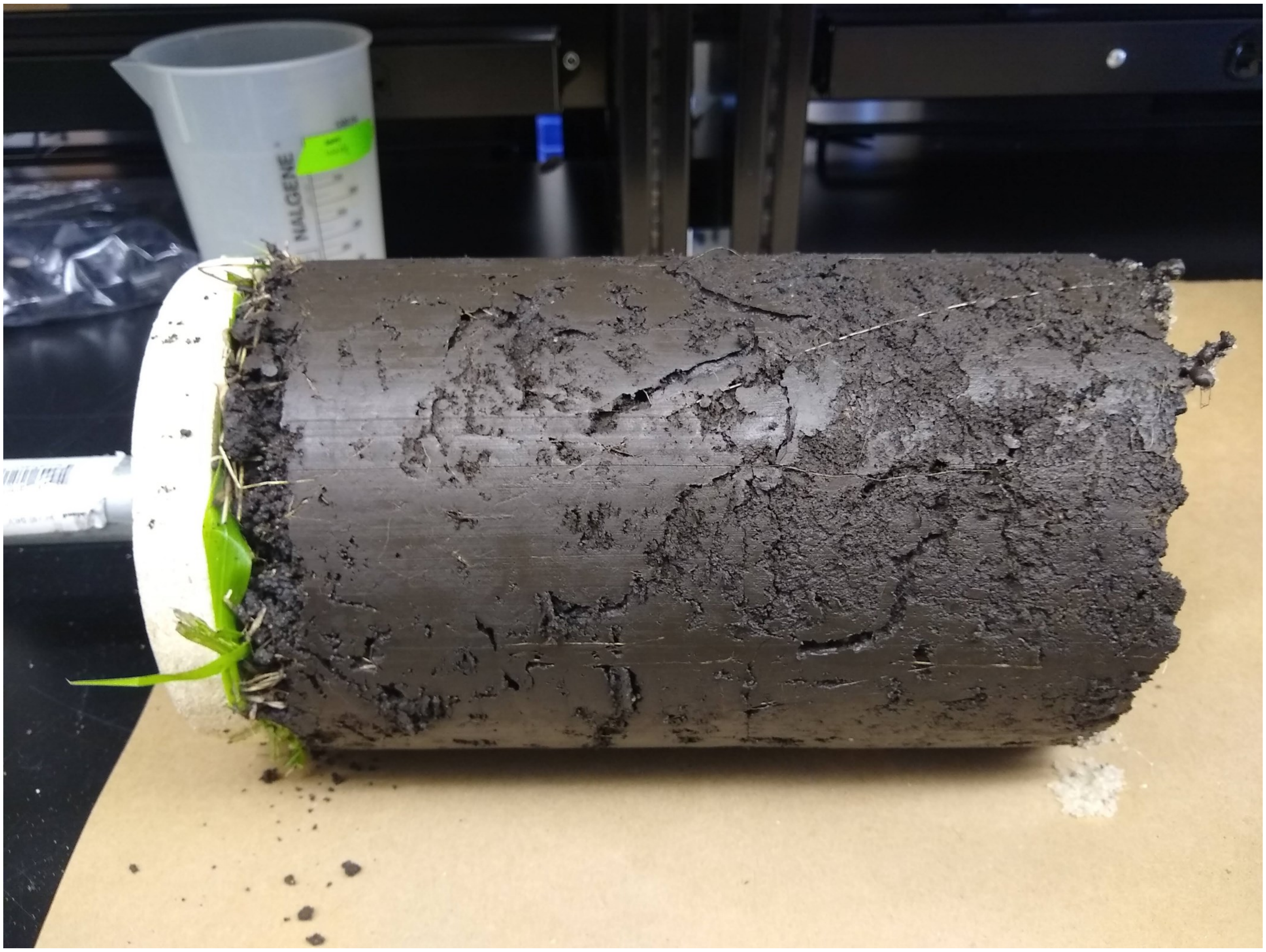
Tracking energy and matter flows, into, out of, and within systems helps one understand their system's behavior.

CCC descriptions from ngss.nsta.org/CrosscuttingConceptsFull.aspx



Questions & Answers

with Grace & Laura



What "systems" do you deal with in your research?

We are studying agricultural systems, where we study the intersection of microbes, plants, soil, and water that are involved in growing crops. In our case, these cropping systems also consist of fields, with or without border prairie plantings, which are exposed to a variety of inputs in the course of agricultural production.

How do you decide what to consider a "system"? Are there criteria?

The environment is an immensely complex place with a multitude of interlinking cycles and processes. Dividing up a piece of the environment into a "system" is challenging, to say the least. We often work with a limited geographic area under limited inputs so that we can simplify our experiments. In our work, a "system" is defined in the context of specific experiments. However, within any section of the environment, multiple systems may be present and interacting at any given time.

Sometimes there are good reasons to "draw boundaries" around a system. Have you ever needed to do this in order to study something?

Often we study research questions within a specific geographic location, such as a single field or a single farm or prairie strip. We often draw boundaries around the system based on distance. We will then treat a specific area (such as a field and adjacent prairie strip) as a system for experimental purposes. For this specific area, we make note of environmental factors such as soil type, slope, vegetation, temperature, moisture, etc. We can then evaluate whether the results within our system may be applied to other systems based on environmental similarity. However, during this process it is important to remember that the environment is extremely complex and it is often impossible to account for all factors and inputs within your chosen system.

Do you investigate any feedback loops in your work? If so, what are they and how do you study them?

The movement of bacteria in the environment can exist as an interesting feedback loop. As bacteria compete for resources for their survival, some populations may survive while others die out. This leads to shifts in the existing populations. And on and on it goes. These feedback loops result in the evolution of various populations, such as antibiotic resistant populations, over time.

What forms of energy are most commonly associated with the systems you study?

Energy for the microbes we study would be in the form of nutrients. Examples of these nutrients could include carbon, iron, or compounds released by plant roots. If these metabolically useful compounds are scarce, microbes may fight over them.

In what circumstances do you notice matter and energy flowing or cycling through the systems you study?

When manure is released into the environment the nutrients in it may cause a "bloom" of microbes which grow and reproduce faster because of the added energy source. In turn, the growing microbes will eventually die or be killed and then eaten by other microbes. These consuming microbes will gain energy from the dead, and go on to grow, divide, eat, and be eaten. In this way the flow of energy continues through and within the system.

What cycles are most important in your research? What, specifically, do you study about them?

The most relevant cycle for our research involves the repeated application of various fertilizers to agricultural fields. We are interested in the impact that manure application, and organic fertilization of crop fields, can have on soil and water microbial communities. We study the short-term and long-term consequences of this fertilization cycle.

We study the short-term consequences by monitoring how (and how fast) bacteria spread from manured fields. We study the long-term consequences by studying how long contaminants persist, and how quickly microbial communities change or recover after manure application.

Highlighted Resources for the Classroom

Dr. Howe's Genomics and Environmental Research in Microbial Systems (GERMS) Lab
The official web page of Dr. Howe's Lab. Discover her research projects, meet the team, and learn about opportunities to join the exciting journey!
http://www.germslab.org/research/

@ISUWaterChicks Twitter feed
https://twitter.com/ISUWaterChicks

Helping Students Make Sense of the World Using Next Generation Science and Engineering Practices
An amazing guide to understanding the NGSS SEPs, how to engage students in the SEPs and what do the eight practices look like in the science classroom?
https://my.nsta.org/resource/105619/helping-students-make-sense-of-the-world-using-next-generation-science-and-engine

Appendix G of the Next Generation Science Standards
Outlines how the Crosscutting Concepts connect with the Framework for K-12 Science Education and provides detailed information about each CCC.
https://www.nextgenscience.org/sites/default/files/Appendix%20G%20-%20Crosscutting%20Concepts%20FINAL%20edited%204.10.13.pdf

Crosscutting Concepts: Strengthening Science and Engineering Learning by Jeffrey Nordine and Okhee Lee
A book available on the NSTA bookstore that discusses how teachers can best design 3D instruction for all students by using the CCCs.
https://my.nsta.org/resource/123163

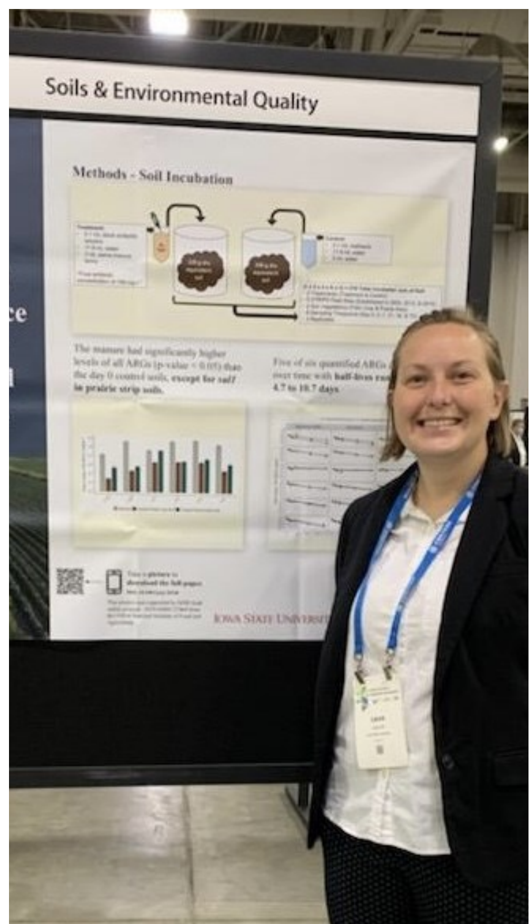
Print-It-Yourself NGSS Classroom Posters
A set of printable posters for the NGSS SEPs, DCI topics and CCCs.
https://neuron.illinois.edu/NGSS-posters

Integrating CCCs into Assessment Tasks
A great resources that includes possible student prompts for use on assessments.
https://stemteachingtools.org/assets/landscapes/STEM-Teaching-Tool-41-Cross-Cutting-Concepts-Promptsv2_2021-10-07-214154.pdf

Implement: PLC Work Sessions

- Consider an upcoming unit of instruction in your science classes. Which CCCs are required for students to learn, if any? Which CCCs are suggested, if any?
- How might an authentic research project (like the ones highlighted in this resource) connect with the learning goals of your upcoming unit of instruction?
- How might the research connect with Science & Engineering Practices and Crosscutting Concepts in the Next Generation Science Standards (NGSS)?
- What will students be interested in? Is the topic/s something that will connect with students' interests and identities? Remember, while some activities may seem really "flashy" and get students' attention, there may be other experiences that engage students more deeply.
- Are there way to build in aspects of equity or social justice into the work? How does students' use of the CCCs and associated conceptual understanding make lives better?

Partnering with a Researcher



- Working with authentic problems or community issues engages students and builds a strong sense of purpose to the learning experience. Partnerships should be formed around these real situations, events or phenomenon so that the products are worthy of students' time and attention.
- Questions to consider as you engage with a research partner:
    - What are the values, goals and needs of this partnership?
    - What strengths does each person bring to the partnership?
    - How might students gain from this experience in ways that they would not have without the partnership?
    - Does the partnership address the deeper needs confronting the teacher, students and researcher?
    - How is your partnership tethered to an existing organizational structure, or made part of a new structure that is supported by your current systems?

And, even more NGSS Crosscutting Concepts

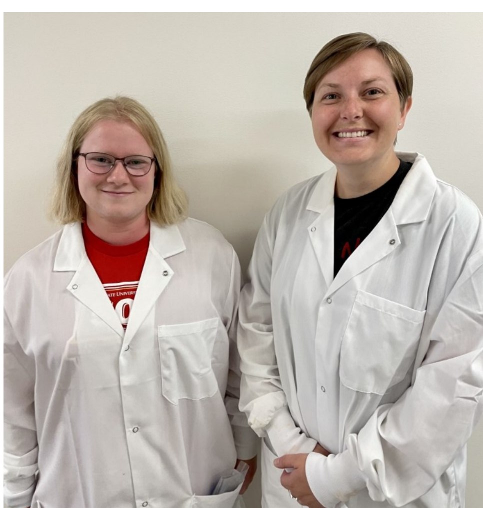
Structure and Function

The way an object is shaped or structured determines many of its properties and functions.

Stability and Change

For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand.

CCC descriptions from ngss.nsta.org/CrosscuttingConceptsFull.aspx



Questions & Answers

with Grace & Laura

What examples of "structure influences function" do you see in your work?

The structure of a field, including the crops being grown, slope, soil type, presence of tile drainage, and other factors can all have an impact on the best management practices that we might employ to improve water quality downstream. Certain management practices will have improved function over others at differently structured fields. Once a best management practice has been identified as a good fit, the structure of that practice directly relates to its function in the field. For example, some of our experiments aim to develop a design tool that could take environmental factors into account when calculating an ideal width for a prairie strip at a given location.

Do you ever intentionally manipulate an object/organism's structure to see how the function is affected?

In order to test a hypothesis we may identify a variable that we would like to investigate. Next we'll design various treatments that could manipulate that specific variable. As mentioned before we'll typically employ positive and negative controls so that we can make comparisons and identify the functional outcome produced by the variable investigation. For example, when studying prairie strips' function of removing resistance contaminants from runoff, we may test field plantings with or without a bordering prairie strip. Our changes to the structure of the field layout may change the function of the system.

Are most of the systems you study stable or unstable? How do you know?

These systems are relatively stable over the long term, but in the short term they can be unstable. For example, immediately following manure application soil microbial communities can change significantly through the introduction of new bacteria and high levels of nutrients. However, after this initial change these microbial communities tend to return to their pre-manure composition by the time manure is applied the next year.

In general, what factors affect the systems you study to become unstable?

Changes in inputs, such as adding manure or synthetic fertilizer to soil, can cause a soil microbial community to become unstable and change at least in the short term. Other factors could include drought, heavy rainfall events, or tillage.

How are the systems you study affected in the long term by gradual changes happening now?

Drought or wetness and temperature changes have a strong effect on environmental microbial communities. As the climate changes, these environmental factors will change dramatically and we can expect to see a shift in microbes as well.

IMpACT in Classrooms

The Implementation Map for Administrators, Coaches and Teachers (IMpACT) is a tool designed as a self-reflection to assist in determination of the level of implementation of the Iowa Science Standards and the five innovations of the Next Generation Science Standards (NGSS). These innovations include: the use of relevant phenomena, three-dimensional learning, coherence of instruction, integration of math and ELA, and a focus on addressing the needs of all learners.

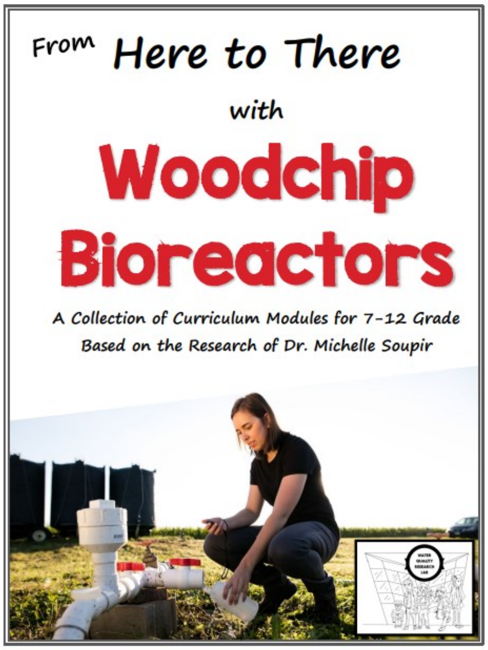
Additionally, the IMpACT gives teachers intentional language around the implementation of the Iowa science standards. The descriptors for each aspect of implementation should provide insight into what actions teachers can take to deepen implementation of the standards and help focus ongoing professional learning. Linked resources on IowaCore.gov provide targeted opportunities to learn more about each aspect.

Below are selected features from the IMpACT which address the Science Crosscutting Concepts directly. While there are certainly other connections to be made, these are simply a place to begin. Check out https://iowacore.gov/content/science-resources for more information!

The IMpACT implementation map was developed by and is the intellectual property of the Iowa Department of Education.

Expanding Implementation	Implementation	Beginning Implementation	No Implementation
Criteria 1—Authentic Learning Experiences			
Students examine and experience science content in authentic ways that encourage greater depth of knowledge and build towards answering essential questions. When appropriate, students use science concepts from different domains (Earth/space, life, physical) to construct explanations.	Students interact with science content within one domain (Earth/space, life, physical) by figuring out phenomena. Any connections to prior learning or across science domains is loose or requires teacher prompting for students to see the connections.	Students interact with science content in some ways that encourage greater depth of knowledge (i.e. students read about a phenomenon or talk about how scientists/engineers engage with a related phenomenon or problem) but do not apply the content to real-world situations or phenomena.	Students interact with the science content mostly through reading a text, answering teacher-developed questions, or completing worksheets.
Criteria 2—Three-dimensional Learning			
Learning is framed by big ideas of science/themes (cross-cutting concepts) in a grade-appropriate manner that would allow students to make sense of phenomena within or across disciplines. Students use cross-cutting concepts to connect more	Learning is framed by big ideas of science/themes (cross-cutting concepts) but likely would not be explicitly seen by students without teacher prompting or guidance.	Learning may be framed by big ideas of science/themes (cross-cutting concepts) but connections are implicit or very loosely connected.	Learning is not framed by big ideas of science/themes (cross-cutting concepts) and concepts are disconnected from unit to unit.
Students use elements of the SEPs, CCCs, and DCIs to make sense of given phenomenon/ problems and are able to transfer their understanding/skills to explain related phenomenon or design solutions to new, related problems.	Student engagement in making sense of phenomena/designing solutions requires student performances that integrate grade-appropriate elements of the SEPs, CCCs, and DCIs.	Students engage in all three dimensions, but they are incorporated as 3 separate entities. Instructional activities utilize two of the three dimensions (disciplinary core ideas, or science/engineering practices, or cross-cutting concepts).	Students learn the three dimensions in isolation of each other. Instructional activities appear to only utilize one of the three dimensions with student learning centered on facts; content is an end in itself.

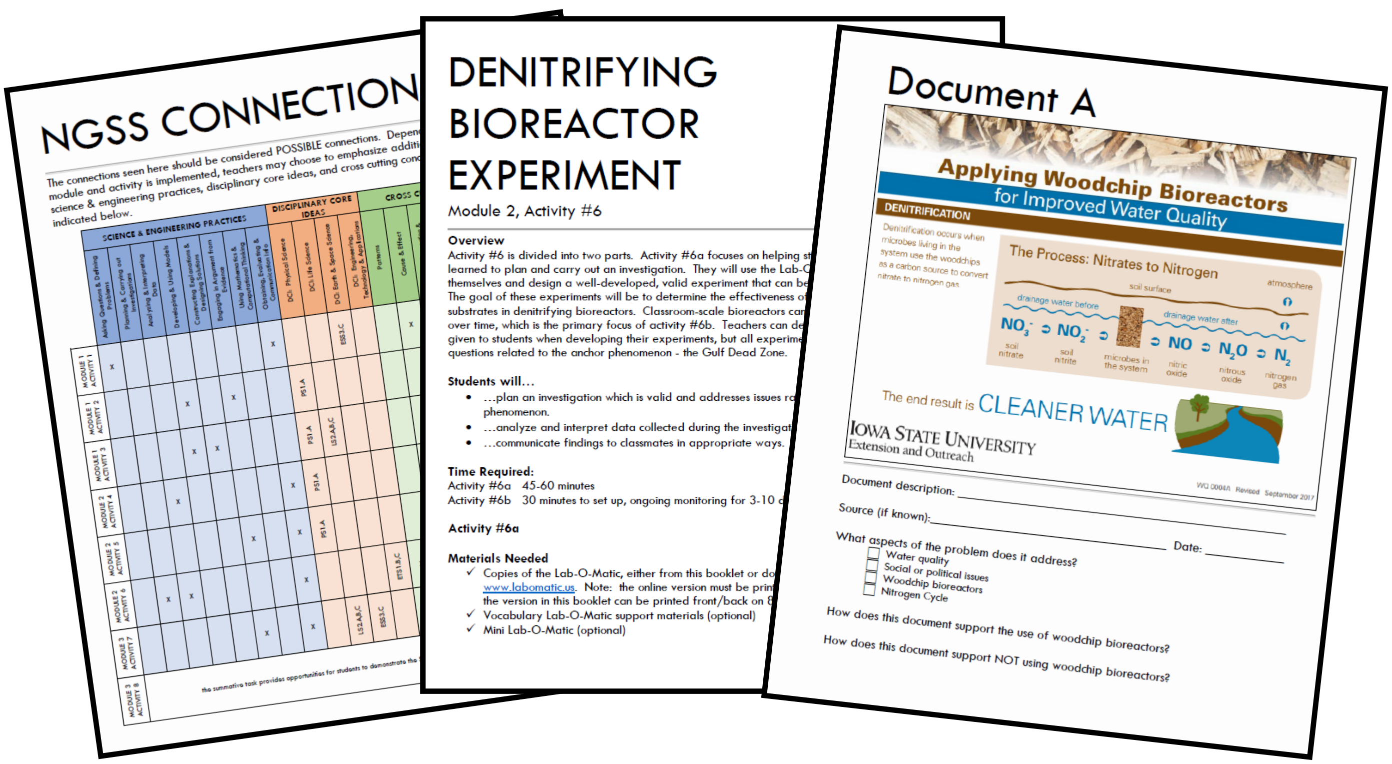
Expanding Implementation	Implementation	Beginning Implementation	No Implementation
Criteria 3—Coherence			
In designing and implementing instructional units, the teacher uses knowledge of the progressions of all three dimensions (DCI Matrix, SEP progressions, CCC progression;) and actively seeks information from students about previous instructional and life experiences to build upon prior knowledge and skills.	The teacher is aware of the progressions of all three dimensions (DCI Matrix, SEP progressions, CCC progression;) and works to connect current learning to past concepts but does not attempt to uncover what knowledge and skills students bring to the unit from life experiences.	The teacher is aware of past experiences students have engaged in but only for the reason of not repeating them in the current grade level.	The teacher is unaware of prior learning and experiences so each instructional unit starts from scratch with foundational ideas and skills.
Criteria 4—Appropriate Integration of ELA/Literacy and Mathematics			
Students use journals/notebooks to record and reflect on data/evidence. Students appropriately communicate scientific ideas/designs to different audiences through multiple modes of expressions including drawing, writing, video, etc. and use self, peer or teacher feedback to revise their understanding or to improve their communication skills.	Students utilize science notebooks/journals as a way to record information in words, drawings, graphs, etc and as a way to organize their own ideas and explanations, but do not have the opportunity to use peer or teacher feedback to revise their understanding or to improve their communication skills.	Students use journals/notebooks to record and organize information and build on these ideas throughout their learning.	Students record information on worksheets or in class notes but do not refer to these items in subsequent learning experiences.
Students interact with each other and use appropriate disciplinary language/vocabulary when they conduct investigations; represent and interpret data; negotiate understanding; gather additional information; and develop explanations, models, and arguments.	Students interact through structured whole-class discussions and small group work to defend their claims with evidence and use their interactions to negotiate understanding and/or to revise their explanations/models/arguments. Students' use of disciplinary language/vocabulary is an after-thought instead of a focus of the interactions.	Supports interact through structured whole-class discussions and small group work but the interactions do not promote student discourse that allows for negotiating understanding or providing peer feedback.	Students interact predominantly with the teacher through answering questions that communicate their understanding of science content or processes. Students experience science vocabulary as information/facts to be learned through disconnected practice or memorization.
Criteria 5—Supporting ALL Learners			
All students are provided necessary support (e.g., scaffolding, extension, or accommodations) to aid in the sense-making process. Students use additional and/or related phenomena within the targeted DCI to stretch their use of the SEPs and conceptual understanding (CCCs) for enrichment when they demonstrate mastery. Engagement in these practices is language intensive and requires students to participate in intentional science discourse. Differentiation occurs within and across all three dimensions and allows all students to grow in	Learning experiences are designed to differentiate so that all students are appropriately challenged in their sense-making and communicate that each and every student is capable of learning and doing well. Planned learning provides opportunities for students to use multiple modes of communication as they present ideas or engage in reasoned argumentation. All students engage in the SEPs as part of the scientific sense-making process as they develop scientifically-based conceptual understandings (CCCs) to explain phenomena (DCIs).	Learning experiences are designed for the "average ability" student. Accommodations or modifications are in place for students, as required by documentation (i.e., IEP and/or 504 plan). Students' use of the SEPs is limited and lacks intentionality and therefore does not support conceptual understanding (CCC) to explain phenomena (DCIs).	Learning experiences are aligned to the "average ability" student, with little-to-no differentiation for diverse learning styles and students' needs. Planned learning provides limited or no opportunities for students to practice the SEPs, develop conceptual understanding (CCCs) or explain phenomena (DCIs).



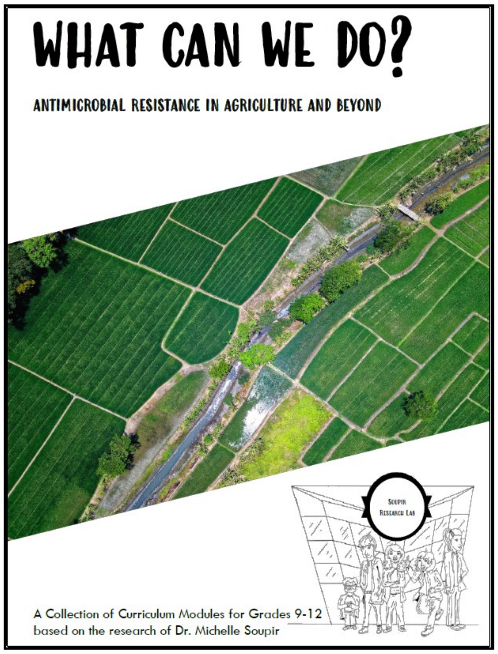
Bioreactors for the Win!

Many parts of the Upper Midwestern United States have wet soils that require drainage in order for them to be used for agriculture. Draining of subsurface water (tiling) in farm fields is a practice that farmers have used for more than 100 years because doing so results in a significant increase in crop yield. Concerns have grown, however, about the effect this practice has on the movement of pollutants (i.e., nitrates and phosphates) through fields and into waters. systems. Nitrate (NO3-1), which can be present in high amounts in drainage water, makes its way into streams, rivers and lakes where it unbalances ecosystems and can result in hypoxic conditions, as we have seen develop in the Gulf of Mexico, also known as the Gulf Dead Zone.

Woodchip bioreactors have proven to be a simple, yet highly effective way to remove nitrate pollution without impacting current land management practices. Field runoff water is collected via tiling and diverted into the bioreactor, which is essentially a buried trench filled with woodchips. Denitrification occurs when microbes living on the surface of woodchips (or other suitable material) use the wood as a carbon source to convert nitrate to nitrogen gas (N2). The result is cleaner water which can be discharged into existing streams and rivers.



These curriculum materials can be found at boec.biotech.iastate.edu



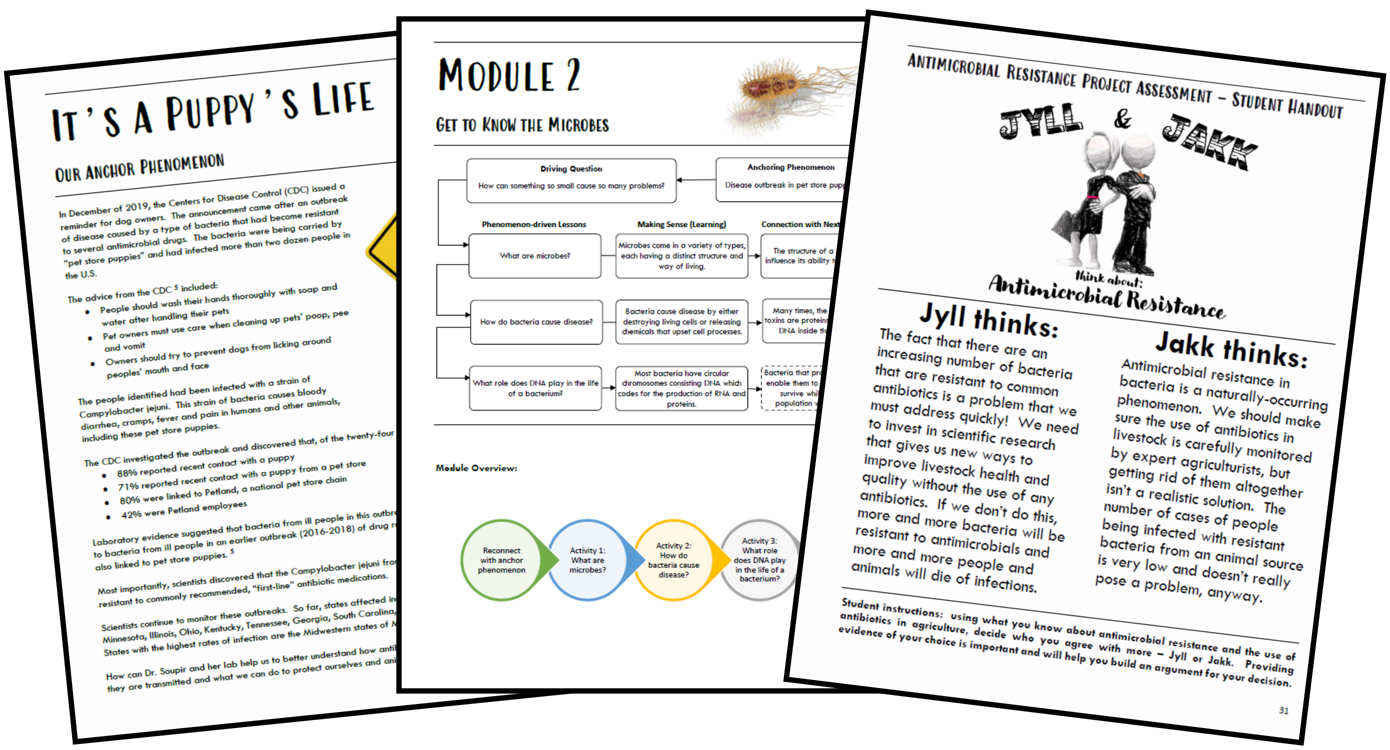
It's a Puppy's Life

Antimicrobials are used widely in animal production. They improve animal health and animal welfare, and also enhance animal growth rates and raise animal productivity. The use of antimicrobials, however, can lead to the emergence of resistance and the transmission of resistant genes and resistant bacteria between species.

Access to effective and cost-efficient antimicrobials is critical for human and animal health, animal welfare and food security. The potential consequences of antimicrobial resistance include reduced food production, reduced food security, greater food safety concerns, higher economic losses to farm households, and contamination of the environment.

The condition of antimicrobial resistance (AMR) develops when potentially harmful organisms such as bacteria, viruses and fungi no longer respond to medications generally used against them. AMR continues to pose a growing threat to the health of both humans and animals, since infections will linger and spread if the treatments we have for them are no longer effective.

In this curriculum, students will learn about a particularly "lovable" phenomenon that will, no doubt, engage them in further making sense of important concepts and topics.



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Notes...

Biotechnology
Outreach

...and thoughts.