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Science Communication in Agricultural Education

EDITOR COMMENTS

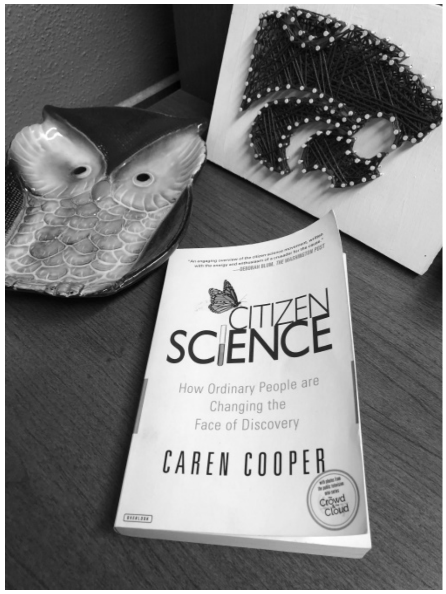
Preparing Our Students to be Science Communicators

by Gaea Hock

As agricultural educators, we spend the majority of our day teaching and communicating about science. Our students are encouraged to learn basic concepts, apply them to situations, and think about how they can solve the grand challenges facing the industry. I would question how well we are actually preparing our students to communicate the science of agriculture. We need everyone involved with the agricultural industry to be an effective science communicator. How do we accomplish this?

One book I recommend you integrate into your classroom is *Citizen Science: How Ordinary People are Changing the Face of Discovery* by Caren Cooper. Each chapter of the book is devoted to a different area of science. There are chapters on Ornithology, Entomology, Microbiology, Conservation Biology and several others that have connections to agriculture, food, and natural resources. I envision this book being a catalyst to get students excited to conduct their own research study or engage with an existing citizen science project. You could also use it to kick start ideas for several FFA competitive events including the Agriscience Fair, Prepared Public Speaking, Ag Issues Forum, and Marketing Plan.

When you host events for your school or FFA chapter consider how you can make them more meaningful, impactful, and educational. For example, almost all FFA chapters host some type of "Day on the Farm" event. How can



your students communicate scientific concepts during that event? What are ways to encourage students to learn the science involved in the segments of the agricultural industry showcased at the event?

Also, consider what assignments you could add to your existing classes to help students learn to communicate about the science of agriculture. One idea would be to have them create a short educational video to share via social media. The more fun they have with it, the better! Another would be to "explain it to me like I am five" activity to encourage them to break down a complex scientific concept into something more understandable.

As you work to teach your students, are you also thinking about them being ambassadors for agriculture and science? Can your students articulate the importance of technological innovation? Are they able to communicate their understanding of biotechnology, genetics, and chemical composition of products in a manner the average citizen can comprehend?

The world we live in continues to become more and more removed from agriculture. I would argue that society is also becoming more and more distrustful of scientists and agriculturalists. We need to develop students who have a high capacity for critical thinking, seek the truth, and stand up to those who would wish to deny the scientific facts surrounding key issues.

As you read each of the articles in this issue, reflect on how you can prepare your students to be science communicators. Consider how you are teaching key concepts and ask students to not only regurgitate scientific information, but also share their knowledge with others. We need to work to prepare all of our students to face the grand challenges in their local, state, national, and global communities.

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Science Communication in Agricultural Education

by Taylor K. Ruth

I cannot tell you how many times I have heard students in my agricultural communications courses say, "By the year 2050, there will be more than 9 billion people on Earth, and we have to find sustainable ways to feed them." However, I can tell you how many times I have heard a member of the general public bring that point up as their top concern – once. I can also tell you some other things I have heard in my research asking consumers about their perceptions of agricultural science: "I don't care if farmers make more money from this new technology. That means I lose money," "I don't want to be the guinea pig for these new innovations in agriculture," and my personal favorite, "I wouldn't buy citrus that was genetically modified through the use of a virus vector. Vaccines cause autism in children." The logic in these reasons for not supporting innovations in agricultural science might be flawed, but the concerns and fears are very real.

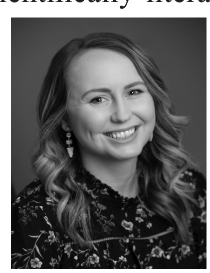
We cannot expect everyone to make 100% rational decisions when it comes to science and technology. Not because these people are not smart enough or not educated enough, but because we cannot expect everyone to care about the same things we care about. In those same conversations I described earlier, we were talking to consumers about genetically modifying citrus to save the industry from a bacterial disease infecting orange groves. Telling consumers this new technology would save the industry was something they simply did not care about. They told us they actually cared about losing the family memories of squeezing fresh orange juice with their children or not having limes to make margaritas with on a hot summer day.

These conversations with consumers illustrate two things: (1) people care more about how science impacts them personally opposed to how it impacts citizens globally and (2) as a discipline, we are facing critical issues related to science literacy, or how well people can apply and utilize science in their day-to-day lives. While science communication, or communication from scientists to non-scientists about their research, can help to address these issues in science literacy, there is an equal opportunity for us to start fostering a scientifically literate society with our students.

We have to start challenging our students' beliefs and prior notions related to agricultural and environmental sciences and have them put themselves in the shoes on non-agriculturalists. Have them understand the valid concerns consumers express about their food and discuss how to communicate about those concerns rather than simply provide people "the facts" without context. Teaching our students to critically consider the issues in agriculture will also increase their own science literacy.

I have always seen agricultural education and agricultural/science communication as two sides of the same coin. We both want our audience, whether students or consumers, to be able to analyze and apply scientific concepts in their lives. Students enrolled in agricultural education classes will not only be the ones driving scientific policy in the future through their votes and purchasing decisions, but also the ones helping to communicate about agricultural sciences to their peers, friends, and family. Therefore, it is critical for us to prepare these students to be both consumers and communicators of science. This issue provides useful tools and programs to integrate science communication and science literacy in the classroom and covers topics including how we can learn from our mistakes in science, use science communication to teach students new concepts, and even how we can use graphic novels to teach about food safety.

My hope is this issue sparks some ideas and can help you to challenge students to think critically about the research they see in the news and reflect on how they use science every day. Most importantly, I hope your students can understand there are multiple perspectives to critical issues in agricultural and natural resources, and before we start stating the facts we know to be true, we should also stop and listen to our audience's concerns. Listening, and communicating about what your audience cares about, is the first step to delivering effective science communication and developing a scientifically-literate future.



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Streaming Science: An Intentional Educational Approach for Developing the Next Generation of Science Communicators, Educators, and Extension Specialists

by Jamie Loizzo

We often separate the disciplines of science communication, education, and Extension into their own specific categories, specializations, and degree programs. Science communicators are frequently described as professionals who write, create videos, websites, plan events, and other skills-based activities. While science educators are said to be teachers in classrooms who do the day-to-day work of educating youth. Extension specialists are then typically viewed as scientists and educators who deliver a variety of programming in multiple formats and settings to youth and adult learners.

Where do these domains, theories, skills, and activities overlap? How do we prepare the next generation of science communicators, educators, and Extension specialists to work across disciplines for public science engagement that leads to science-based decision-making for positive life-changing impacts?

Non-formal/Informal/Online Science Communication, Education, and Extension

I would like to kindly encourage researchers, practitioners, and students among the different disciplines to consider the areas of non-formal, informal, and online environments as a potential intersection and collaboration space for our research, teaching, and engagement efforts. Non-formal environments might include an Extension specialist giving a program at a local school about nutrition. Hence, the instruction is outside of the usual school curriculum, yet the specialist delivers the program within classroom walls. Informal communication, learning, and engagement happens outside of schools and might include viewing a documentary, reading a magazine, or visiting a museum. Online environments might include Massive Open Online Courses (MOOCs), social media communities of practice, a website, or blog. As a further example of where our different specializations overlap, I often use the following table with science communication students to visually demonstrate how our efforts, approaches, and terminology overlap.

In science communication, we say...	*In science education and Extension, we say...*
Target Audiences	Target Learners
Key Messages	Learning Objectives
Deliverables/Outlets	Curriculum/Lesson Plans
Analytics/Tracking	Assessment/Evaluation
Behavior Intention and Change	Behavior Intention and Change

It is critically important that we prepare 21st century science communicators, educators, and Extension specialists to collaborate for creating effective communication, education, and programming experiences across our various theories, approaches, terminology, and non-formal spaces that moves beyond simply pushing information, but rather for promoting two-way interaction, dialogue, learning, and engagement about agriculture related science content impacting everyday lives.

Systematic, Intentional Instructional Design: Project-Based Learning

As a response to this need to develop multi-disciplinary critical thinking and creative researchers and professionals, *we must take a systematic instructional design approach for intentionally creating immersive learning experiences for students to fulfill these current and future leadership, faculty, and practitioner roles.*

First, we must ask: what competencies and skills should 21st century science communication, education, and Extension students and graduates have? The answer: there are many. Great places to start, broadly, include:

Science literacy - knowledge of science, current issues, the scientific worldview, scientific inquiry, and the nature of science

Media literacy – how to identify bias, critically evaluate information, read and cite peer-reviewed research

Multimedia skills – writing, photography, video, audio, web, social media, software, and hardware

Public engagement – needs assessment, target audience/learner identification, cultural awareness, dialogue strategies and tools, evaluation

Project-based learning (PjBL) is one instructional design approach I have repeatedly applied, researched, and found effective for engaging students in the above competencies in my courses across three different institutions to intentionally engage students from a variety of backgrounds in science communication, agricultural education, and extension learning and contexts. PjBL includes the following steps: a challenging problem or question, sustained inquiry, authenticity, student voice and choice, reflection, critique and revision, and a public product (BIE, 2019).

Some examples of how I have applied PjBL in science communication classes over recent years are:

Students in a mobile video course worked with an Extension small farms team to create videos about organic agricultural practices that were shared via DVDs with the group's members and stakeholders

Students in a podcasting course worked with the university's big data consortium and scientists to create podcasts about big data concepts and current research for the consortium's members, stakeholders, and online public audiences

they often never meet a university scientist, Extension specialist, or step foot into a university lab, field site, or non-formal/informal education site. Instead, students might go through the motions of submitting assignments and creating projects for fictitious communication clients. The American Association for Agricultural Education (AAAE) national research agenda (2016) calls us on us to develop immersive, active, and hands-on learning experiences for students' deeper understanding and learning. It is within this space that I imagined the Streaming Science (https://www.streamingscience.com) student-driven, faculty-facilitated online science communication platform (founded at the University of Nebraska-Lincoln in 2016 and extended to the University of Florida in 2018). In its simplicity, *Streaming Science* is a website and social media presence that is hopefully appealing to the eye. In its complexity, there is a lot more going on behind the scenes. The project is meant to be a positive and productive collision of students, scientists, and Extension specialists, creating and sharing real-world innovative multimedia communication products and engagement programming for

Students in an instructional and communication technology graduate course worked with university museum scientists to create, deliver, and research an electronic field trip for middle and high school audiences about the university's bat houses, museum collections, bat population genetics research, and climate change

Within each of these examples, students not only developed multimedia science communication skills, but they also worked on driving questions to investigate science concepts such as organic production methods, big data, and wildlife genetics. Through their sustained inquiry and reflection, they created real-world science communication products for public audiences. This combination of learning and applying skills coupled with science learning has transformed students' content knowledge, attitudes, and behavior intentions toward science concepts, scientists, and Extension programs. The PjBL approach has also broadened students' perceptions of the roles and capabilities of science communicators for developing public science engagement and increasing science literacy.

Streaming Science as a Teaching, Research, and Engagement Platform

Through my work at three different institutions, I had the realization that science communication students often graduate with bachelor's, master's, and doctoral degrees of science (not arts), yet a variety of audiences – and most of this happens through PjBL designed courses and grant projects.

In its current form, *Streaming Science* is an outlet for students' multimedia work to reach public online audiences, as well as a platform for connecting with PK-12 teachers and youth. *Streaming Science* gives faculty and students a collective voice and presence for experimenting, disseminating, and researching communication products and program engagement about agricultural and natural resource topics. On the site, you will find student-created videos photo essays, and podcasts created as part of science communication courses and grants. Additionally, *Streaming Science* has offered three live web-casted electronic field trip programs in the past three years and recently, a new *Scientist Online* offering connecting youth with scientists via Skype in the Classroom. *Streaming Science* facilitates the 'public product' final stage of the PjBL design. Students also use related *Streaming Science* social media to post and go live via Facebook and Twitter from science-related events, hence actively participating in real-world online communication. While the program has proven successful in sharing information and impacting attitudes and learning, there is still much room for increasing dialogue and engagement with the platform.

Future Growth of Science Communication + Education + Extension Engagement

To grow the Streaming Science platform, PjBL courses, and efforts to effectively collaborate between science communication, education, and Extension areas, we must continue to be innovators in teaching and research in non-formal, informal, and online environments for increasing science literacy and engagement. The next iteration of *Streaming Science* aims to grow, examine, test, and implement strategies with systematic instructional design and research with the following aims:

Develop solutions-focused, constructive science communication for impacting decision-making and behavior change. *Streaming Science* will purposefully teach solutions communication rooted in positive psychology that flips traditional journalism on its head. Instead of reporting on problems, *Streaming Science* faculty and students will create content focused on scientific and social solutions to global agricultural and natural resource problems and invite dialogue.

Move beyond 'The Deficit Model' and echo chambers– do not simply push facts and expect audiences/learners to change opinions and behaviors. Instead, invite engagement and dialogue by hosting interactive programs and implementing tools for synchronous and asynchronous conversation. This will involve finding ways for diverse audiences to submit content back to *Streaming Science*, instead of only consuming *Streaming Science* content.

Continue to explore new tools and interactive technology methods for meeting audiences and learners where they are. Students will continue to test and apply emerging technologies such as 360-degree cameras, drones, and more for connecting diverse groups to spaces, places, scientific content, and scientists they may not have otherwise had the opportunity to explore.

Ten, twenty, thirty years from now – and beyond, it will be amazing to see where immersive learning and engagement projects such as *Streaming Science* take our science communication, agricultural education, and Extension disciplines. There is no limit to this type of intentional teaching, research, and collaboration for fostering growth in ourselves, our students, and graduates.

If you are interested in learning more about Streaming Science, PjBL, or collaborating, please contact me!

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Integrating Science Communication and Literacy into the Classroom

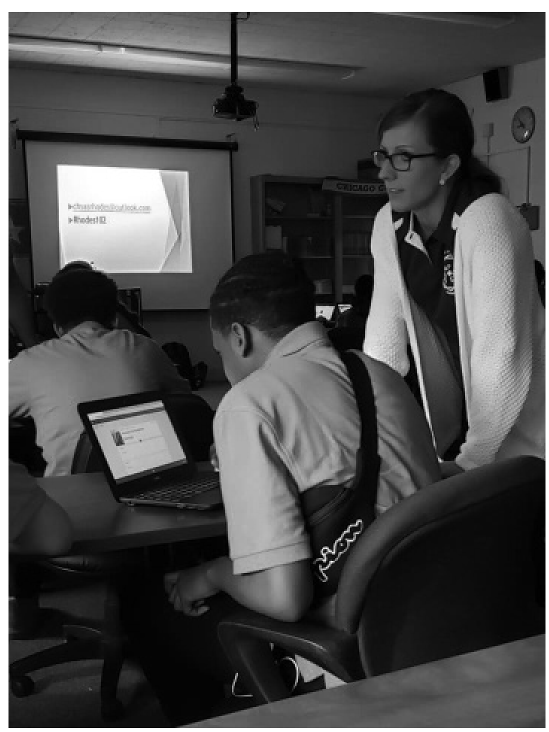
by Jordan Johns

To complete my student teaching experience, I was placed at Chicago High School for Agricultural Sciences, a magnet school on the southwest side of Chicago. Freshman year, every student takes the Introduction to Ag Careers and Leadership course. Sophomore year, students spend approximately thirty days in each of the school's six agricultural pathways. Junior and senior year, students spend 102 minutes a day in one pathway that is determined at the conclusion of sophomore year. The six pathways offered at CHSAS are: Agricultural Finance and Economics, Agricultural Mechanics and Technology, Animal Science, Food Science and Technology, Horticulture, and Biotechnology in Agriculture. I had the privilege of student teaching with Mr. Derrick Rhodes and Mrs. Julie Reynolds. For this article, I'm focusing on some ways in which scientific communication and literacy components were integrated into the Biotechnology in Agriculture I course for juniors.

As one can imagine and others will attest to, there are both unique challenges and amazing opportunities teaching agriculture in an urban setting. CHSAS students will often choose the Biotechnology in Agriculture pathway because of the lab opportunities and the hands-on application of scientific concepts. Given the setting and background of the students in the Biotechnology in Agriculture I course, I tried to connect agricultural concepts to their interests and community assets. Being in the city of Chicago allowed us to draw from a variety of agricultural, scientific, and communication-focused groups, projects, businesses, and practices that influence the city and the lives of individuals in both rural and urban settings.

To begin my student teaching experience, the first unit of instruction focused on soils. After some introductory material, we examined soil samples. The lab consisted of the students developing their own list of materials and methodology, examining samples with a microscope, and illustrating their findings. They then compared and contrasted the respective samples. To enhance the assessment, students read a peer-reviewed, published article that provided an overview of six common microorganisms in soil. The article was complete with images of microorganisms from extremely high-powered microscopes, which enhanced students' understanding of microorganisms' size, function, and role in soil. The way the article was written exposed students to scientific discourse, and the images in the article provided a natural opportunity for us to discuss and review the different types of microscopes and attributes that would be beneficial for examining both soil and microorganisms.

Soil is extremely important, yet students may argue its relevancy. I must admit, there was a lot of engagement and "buy in" created with the construction of an edible soil profile as an interest approach; however, out of all the activities and assessments, our podcasts about soil formation factors were extremely well-received. First, we addressed what a podcast entailed, and students shared if they had a favorite podcast they regularly listened to. As a class, we listened to some short podcasts from a state Farm Bureau. We then identified the general format and conversational nature of podcasts. In groups, students wrote a script and recorded a podcast that addressed each of the five soil formation factors. I encouraged students to relate their podcasts to the soil specifically found in the Midwest and northern Illinois. To review for the summative assessment for this unit, we began class each day by listening to one group's podcast. The students looked forward to listening to their 3 to 5-minute podcasts, and it ultimately connected a form of communication frequently used in the areas of music, health and wellness, and



politics to agriculture and science. As agriculturalists and scientists, we know reaching consumers through a variety of means is extremely important. This assessment encouraged students to be innovative and aware of the latest avenues through which to connect with their target audiences.

Sustainability was another unit of instruction I taught while student teaching. Students devised potential research topics that pertained to sustainability in animal production practices, farming and natural resources, plant production practices, and economic, social, and political contexts. The students then developed a research project and conducted an experiment, and/or read scientific literature, based on their individual area of interest. I found that students had written research papers in classes they had previously taken. Students had also made trifold displays for agriscience projects in the past. However, being a college student at a land-grant university, I found it interesting that the students I was teaching had never been exposed to digital research posters that are presented on computer screens or televisions. At institutions of higher learning and professional development conferences, these posters seem to be the norm. Students at CHSAS are fortunate to have access to Chromebooks, so Google Slides was utilized to create very basic, digital research posters. Students then practiced professionally presenting their posters like they would at a conference.

To conclude student teaching, the final unit I taught was on specialty crops. Being an Agriculture in the Classroom intern, children's books are very near and dear to my heart. In an effort to further enhance these high school students' ability to educate and communicate with different audiences, we compared and contrasted children's books. We looked at the lessons and major takeaways, the incorporation of special elements (famous individuals, references to current literature and special events, historical references, etc.), illustrations, and language (poetry, rhyming, etc.). Not only did students develop and illustrate a story for an age group of their choice, but they also included facts about their selected specialty crop within the storyline. A glossary and information pertaining to pests and diseases, the growing season, environment, location, and genetic modification needed to be addressed. The students did a tremendous job with their specialty crop children's books, and I believe each one of them would say this unit challenged them to think about how to appropriately incorporate scientific terms and communicate agricultural practices in a unique way.

I had an amazing student teaching experience at a tremendous agricultural school, but I know I still have a lot to learn! I'm looking forward to officially becoming an agriculture education instructor upon graduation from the University of Illinois at Urbana-Champaign in May 2019. I'm still working on a "recipe" for incorporating scientific communication practices and literacy into my classroom, but from student teaching I've learned that developing student interest, creating engaging assessments to reach a variety of learners, drawing from community assets, emphasizing innovation, and applying student knowledge in a "real-world" context are some key ingredients!

Jordan Johns is a senior at the University of Illinois at Urbana-Champaign studying Agricultural Sciences Education.

Teaching Students to Become Better Consumers of Science Communication

by Quisto Settle

There's a lot of research out there. Some of it's great. Some of it's not. How do you make sense of it all?

One way is to get a Ph.D. That's what I did. But I wanted to teach at the university level, including teaching research methods. It's not an ideal path for everyone.

So how can we teach students to evaluate research for its meaningful impacts on their lives?

Funny you should ask. I'm going to run over some basic things to teach your students to look for whenever they see news stories, politicians, etc., talking about research.

Society depends on research. Research helps doctors treat diseases, increases fuel efficiency of cars, and improves education. Society needs evidence to make good decisions. As such, research needs to be understood so we can make evidence-based decisions.

Before we begin, it's important to understand that no research project is perfect. They all have limitations. You can't indisputably say anything with one research project. That's an important starting point.

But without further ado, let's go to some basic questions to ask:

Does the research seem too good to be true?

Sometimes research comes out that sounds too good or too outlandish to be true. And usually it is.

A more outlandish example had headlines saying that smelling farts can cure cancer. That statement smells funny.

The study the headlines were linked to had nothing to do with smelling farts. The study involved delivering hydrogen sulfide directly to mitochondria.

The mistake stems from the university's press release, which mentions that hydrogen sulfide is what makes farts and rotten eggs smell bad. And then the media ran with the wrong part of the story.

Society depends on research. Research helps doctors treat diseases, increases fuel efficiency of cars, and improves education.

Does the researcher have personal bias?

This is a trick question. Everyone is biased.

As such, all research is biased. It's biased in how we decide which questions to ask, it's biased in how we set up studies, and it's biased in how we interpret the results and what they mean.

But we can mitigate some of these issues. We can explicitly state our biases as researchers, though this isn't common in many disciplines. We can outline our methods and how we designed the study, which should always be the case. And we can offer alternative explanations for results, which is not as common as it should be.

Every study is biased, and that's ok. But we need to understand biases as we interpret research.

Who funded the research?

Does the funding source really matter? Yes.

University researchers need funding to do their work, not to mention for promotion and tenure.

Funding can come in the form of competitive grants from organizations like the United States Department of Agriculture and the National Science Foundation, but funding can also come from the private sector. There's nothing inherently wrong with private funding, but it opens the door to some less than perfect situations.

One of those situations emerged in climate change research. The vast majority of researchers in the discipline agree that there is human influence on climate change, but there is still political opposition. The opposition commonly cites a small group of researchers who stand

All research is biased. It's biased in how we decide which questions to ask, it's biased in how we set up studies, and it's biased in how we interpret the results and what they mean.

on the other side of the fence.

A kerfuffle arose when one of those opposition scientists, Wei-Hock Soon, was found to have accepted funding from the fossil fuel industry and wasn't disclosing the conflict of interest when publishing papers. The concern is he depends on funding from groups with a vested interested in opposing climate change legislation, so his research appears less trustworthy.

How is the research being shared?

Not all outlets are created equally.

The best scenario is a peer-reviewed journal. This is where other researchers review a paper and judge it for its merit. It's not a perfect system, but it's the best system currently.

The next tier down consists of peer-reviewed conference papers and presentations. You also have less formal publications where the researchers or universities put out results directly. The research isn't necessarily untrustworthy, but it hasn't been vetted to the same degree of a journal publication.

When peer-review doesn't occur, things get messy more quickly. One example is a study by a pair of Harvard economists that was being used as support for austerity in the 2012 election. The study was published in an academic journal but in a non-peer-reviewed issue.

There was just one problem: A graduate student at another university tried to replicate the results of the study and couldn't. It wasn't until the student received the Harvard researchers' dataset that the errors were found.

Before other researchers could vet the research, real-world consequences were already happening.

Who were the participants?

As much as possible, you want apples to apples comparisons in research studies. In other words, if you want to understand how exercise impacts elementary students in California, study elementary students in California. You want as much similarity between who was in the study and whom the results are supposed to apply to.

A common issue with research is that it isn't easy to access all populations. A lot of times, university researchers turn to a group that is close at hand: college students.

The problem is that it's difficult to say that college students are representative of larger populations. There's a good chance that they're going to be different from the public in terms of age, education, race/ethnicity, and socioeconomic status.

> A common issue with research is that it isn't easy to access all populations.

And when the media reports health research, they're often citing studies involving mice. There's now a handy Twitter account you can follow (@justsaysinmice). All the account does is quote tweet "IN MICE" when the articles talk about research that was done with mice without providing the context that the research was done with mice.

What methods were used?

Different methods of research have different strengths and weaknesses.

Experimental design is often touted as the gold standard of research, but it's not perfect. Done right, experiments are really good at saying whether or not A affects B. But because of the level of control they require, they typically lack real-world context.

Surveys are very common. They allow you to study a broad group of people, but it's difficult to know what caused the outcomes. They're very good at saying what is happening but not why.

Qualitative research like interviews and focus groups give you good depth of information and let you understand people's experiences, but they're difficult to generalize to the larger population.

Meta-analysis or systematic review gathers up all the studies about a topic and analyzes all the results to make conclusions based on multiple studies, not just one study. You get past the flaws of one study. If the same result consistently occurs, you can be more certain of the findings. But even this method is limited because null results, or results that are not what researchers expected, often go unpublished

Are they confusing correlation with causation?

Correlation means two things happened at the same time. Causations means one thing caused the other to happen.

Frequently, media outlets and researchers misuse causation when reporting on correlational research. Correlational research is important, but it can't really tell us the cause of something. It's possible that two things randomly occurred at the same time.

It's also possible there's a third variable causing the other two.

Are they confusing statistical significance with practical significance?

Statistical significance tells the researcher the likelihood that a result could have happened randomly. This is important, but it's not everything.

Practical significance, or effect size, tells us if the result is strong enough to be meaningful.

It's easier to game statistical significance, often called p-hacking, by increasing sample populations or continuously fishing in the data to look for statistically significant results.

Statistical significance tells us if something is random. Effect size tells us if something actually matters.

A good example is bacon and smoking. Statistical significance puts both in the same in the World Health Organization category of carcinogens, but they don't increase your likelihood of cancer the same amount. There's a reason bacon doesn't have a Surgeon General's Warning on it.

What does this all mean?

Research is a logic puzzle. There are a lot of moving pieces to research. We're trying to put the pieces together in the most sensible way. If it looks like someone is trying to mash two puzzle pieces together that shouldn't be, there will be red flags.

And progress is ongoing. One of the more exciting things happening is the emergence of pre-registered studies, where researchers are stating the research they will do and how they will interpret it before they collect, which can help limit shoddy claims.

As you work with students, encourage them to be a little skeptical and ask questions. They'll be better prepared to deal with the onslaught of information in today's environment.

Research is a logic puzzle. There are a lot of moving pieces to research. We're trying to put the pieces together in the most sensible way.

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Informal, Nonformal, and Free-Choice Learning: Engaging with Scientists in Unexpected Places

by Katie Stofer

One of the constant struggles of science communication and public engagement with science is to share science as a living, breathing thing, a practice, rather than science as a body of facts. Recently, more and more types of programs offer a chance for scientists – and by scientists, I mean broadly everyone involved in science, technology, engineering, and math (STEM), plus all the other disciplines that may be associated explicitly or less so with STEM, including agriculture- to share their ongoing work with audiences outside of academia. These programs offer the promise of sharing science and research as a practice as well as involving a broader audience in the enterprise. Today, there are a whole spectrum of opportunities for people to engage with scientists, and more and more frequently these opportunities are designed to meet people where they already are.

Scientists may be hesitant to share their work with broader audiences, especially in the face of at least perceived rising public mistrust and skepticism of science. At the same time, public audiences who do not consider themselves savvy about science may feel they may not be able to adequately discuss their concerns with people who might be able to bring science to bear on larger social and environmental issues in their communities. However, it is precisely because of those hesitancies from scientists and community members that public engagement with science activities, which promote dialogue among professional scientists and other community members, are necessary.

For students, meeting scientists in their communities can provide them with more examples of role models and careers which they could pursue. They can get real advice on what sorts of classes to take and paths to pursue to become a 21st-century scientist, engineer, or any number of professions that benefit from strong science backgrounds, including policymaking, public service, and education. They may meet mentors who can guide them in high school research projects or eventually write them a letter of recommendation for future applications for school or jobs.

Scientists have traditionally shared their ongoing work with each other through conference presentations. In these formats, they often share works-in-progress, often with data collected and only preliminarily analyzed, or in the midst of the data collection process. These programs are expensive for non-professionals to attend, and often focus on details of individual studies rather than bigger picture findings of how the world works, the latter of which is more relevant to broader audiences. While scientists have recognized the need to make their work more accessible, many of their efforts remain in the university rather than in spaces more inviting to the audiences whom they wish to include.

More recently, programs facilitated by informal, nonformal, or free-choice learning institutions (Stofer, 2015) are bringing those scientists out of the conferences and universities. Many of these locations host scientist meet-and-greets or other lecture programs designed for both students and their families. Increasingly, there are even more in public spaces, such as:

-The Café Scientifique model, (http://www.cafescientifique.org/) and Nerd Nite (https://nerdnite.com). These models typically feature one or more speakers but move their events beyond the typical science institutions and host instead in bars and restaurants usually on a monthly or bimonthly schedule;

-Science festivals, (such as http://sciencefestivals.org), and Taste of Science (http://tasteof-science.org). These events, usually held annually, bring together a host of science events and talks over the course of a few days, often featuring hands on activities and shows.

-Pop up museum events, “Sidewalk Science” events such as Experience Daliona’s Sidewalk Science Center (https://www.experiencedaliona.com/sidewalk-science-center), and stargazing nights. These experiences are often scheduled more irregularly but aim to bring science events to places such as parks, scientifically-interesting sites such as active museum fossil digs (e.g. https://www.floridamuseum.ufl.edu/montbrook/), and open prairies with dark skies for astronomical events.

Finally, a much less formal program is the impetus for casual conversations with pairs of

Kirsten Hecht (left) shares live animals related to her research while talking with patrons at Gainesville House of Beer.

scientists and community members where they are hanging out and have some time to discuss, i.e. where community people *already are*. Participants in the Walk with a Doc program exercise while talking with certified medical practitioners.

One version of these science in your backyard programs that I run in the Gainesville, Florida, area is "talk science with me," (https://talksciwme.wordpress.com/) part of the Two Scientists Walk into a Bar network (https://www.rhfleet.org/events/two-scientists-walk-bar). Over the course of a few weeknights and weekends three times per year, multiple pairs of scientists visit locations for a couple of hours each. Locations include bars, coffeehouses, libraries, and laundromats at the moment, and we have plans to expand to the DMV and bus routes.

At each location, the scientists sit with a prominent sign inviting patrons to ask them anything or share their own stories. They have spontaneous, extemporaneous conversations without preplanned materials and ranging over any topics the attendees wish to discuss. Topics are not limited to science but can also include just getting to know the scientists as people, helping to alleviate issues of people not knowing scientists as regular members of their community and seeing them otherwise as "others." One herpetologist brought salamanders to a bar, allowing people to handle and observe the potentially intimidating creatures in a much more relaxed and familiar environment for many people. This program specifically has both urban and rural venues, as our university is about 20 miles away from some of our smaller communities, often making it a barrier for residents to come into the urban center.

In addition to events specifically set up to feature and promote science, challenge your students to find the science in other programs. Science booths and events might take place in art or community festivals. Storytelling events have emerged as regular performances in many areas, with local community members sharing experiences sometimes around a common theme. For example, in Gainesville, Guts and Glory events (https://www.gutsandglorygnv.com) featured their second "Fieldwork Fails" evening of stories at their local natural history museum. Comedy nights could also feature improv about science, and local theater may also include shows such as Proof, about mental illness, or The Nether, about virtual reality. Last but not least, local agricultural sites might feature agritourism, tours and events designed to share their work in agriculture and natural resources, obviously STEM-related but not always marketed as such.

Another set of public engagement models truly encourages dialogue among scientists and community members. Some of these are Community Voices, Informed Choices (CIVIC) from the University of Florida IFAS Extension; On the Table, which covers all manner of topics including science, University of Michigan Teach Outs (online, and all topics). These conversation-driven events are usually facilitated around single contemporary issues such as water conservation. These programs are generally designed for adults, but some of them can be suitable for older students.

Your students can participate as community members, talking with the scientists, or they can also participate as the "experts," sharing the work they are doing with their community. A few ways to find these or create and host these with your students could be:

Find a local version of these existing events for your students to participate in. Take it a step further and partner with them to create a version with your students, either designed by students for other students, such as Teen Science Cafes or designed by students for all community members.

Take existing versions of your events and host them in new community spaces; for example, share your science fair project presentations at the local library.

Develop a new version of any of these events for your area or offer a new venue for hosting existing events in a more accessible rural area, by visiting their links and joining their networks.

Longer-term, work with a larger community group to create a new festival or larger group of events in your area.

Most importantly, find a way to get to know the scientists around you, whether they work at universities or colleges, or industries, or in government or non-profit organizations. They are eager to get their work out to new audiences, and they can benefit by having you as partners and finding ways with you to understand how their science can be impactful to their communities. For a full list of categories of agricultural and STEM venues in your hometown, see Stofer and Rios (2018).

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Enhancing Food Science Literacy with Graphic Novels

by Buddy McKendree and Jason Ellis

Back when we were students, reading a 'comic book' would hardly have sufficed as educational material in a science class, agriculture class, or language arts class. A comic would most certainly be deemed non-technical reading – something suitable for 'fun' reading, but not rigorous enough to provide educational value. Besides, comics were something we read in the 'funnies' section of the Sunday paper to get a lighthearted laugh after a long week.

What we are here to discuss is, why not? Why should a comic – err, graphic novel – not be used in the classroom? Why is it not an acceptable way to capture student interest? Why can it not be a technical reading, increasing students' literacy of scientific terms? Graphic novels are not just reserved for the *Avengers* and other superheroes; they *can be used* to accomplish our educational goals. In this article, we will discuss the benefits of graphic novels, as well as present a free resource to teach food science and safety in secondary education classrooms.

So, what are the benefits? Comics, also known as graphic novels, can captivate readers through a unique structure. Increased use of imagery (i.e., pictures) gives deeper meaning to stories and words, while shorter text passages through storylines keep readers engaged – an important element with decreasing attention spans in today's stimulus-driven world.

However, the benefits of graphic novels are not just a few folks' opinions, as research

supports these claims. Graphic novels are a way to introduce readers to new content (Boerman-Cornell, Kim, & Manderino, 2017; Schwarz, 2006), which effectively sparks readers' interest and can be used to deepen disciplinary understanding (Boerman-Cornell et al., 2017; Schwarz, 2006; Short & Reeves, 2009).

Still skeptical about graphic novels being an avenue for increasing science literacy? Boerman-Cornell et al. posited a few more benefits, including:

- Reinforces comprehension
- Presents new content in a different format
- Illustrates difficult or abstract concepts
- Encourages close reading of text
- Fosters critical thinking
- Negotiates multiple perspectives of thinking and practice (p. 40)

How often do students struggle with new terminology when they are first introduced to it? Or become bored at the introduction of a new topic? Graphic novels can be a tool to help us overcome these challenges by reinforcing comprehension for students as they encounter new terminology, and along the way providing a different format for content delivery. Of equal value, graphic novels help appeal to learners of different modalities while incorporating extensive imagery to help relate abstract concepts (see image below for example of imagery reinforcing the USDA food safety principle of cooking).

While graphic novels are not the end-all, be-all solution, they can be an important tool for the classroom. So, how can these resources be utilized in Agricultural Education? There are many publications already available; with the University of Nebraska publishing items focused on topics like viruses (see http://www.nebraskapress.unl.edu/university-of-nebraska-press/9780803243927/ for more details). More specifically, we would like to highlight a resource that is paired with a Project-based Learning (PBL) curriculum centered on food science and safety, entitled *Food and Nutritional Sciences.*

The Food and Nutrition Science (FNS) curriculum was created through a collaboration between the Nebraska Department of Education and a large USDA grant focused on decreasing the occurrence of foodborne illness caused by Shiga toxin-producing *Escherichia coli.* In an effort to increase public education, researchers developed a curriculum intended for secondary education classrooms, with curricular units focusing on topics like beef food safety, nutrition, caloric needs, and more. In addition, a three-part graphic novel series, entitled *Megaburgerz and the E. coli Outlaws,* was developed to enrich the FNS curriculum (see image below). The entire curriculum, and graphic novel series, are available for download at www.ksu.edu/fns.

The *Megaburgerz* graphic novel series includes three issues, each being 20 pages. The graphic novel series details the experiences of two teenagers beginning work at a fast-food restaurant, 'Megaburgerz.' Through the two teenagers' experiences, readers go on an adventure of epic proportions as they encounter a world comprised of bacteria – it is up to them to determine the good bacteria versus the bad, and figure out ways to halt the bad bacteria in its tracks. Readers are introduced to scientific terminology, including *E. coli*,

and other food safety terminology centering on the USDA's four steps: clean, separate, cook, and chill (see https://www.foodsafety.gov/keep/basics/index.html for more information). To download the *Megaburgerz* graphic novels, click on the "Megaburgerz Comic Series" tab on the FNS curriculum website, www.ksu.edu/fns.

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Embracing Mistakes to Cultivate Scientific Literacy in Our Students

by Anna Warner

As a new teacher, I remember dreading when lab activities didn't go as planned. Who hasn't had a great lab planned and then something goes wrong? You don't get the right results...epic failure! Now your entire lesson is ruined. Or is it? It did not take long for me to realize how much more my students were able to learn when things didn't go as planned. I soon embraced the mistakes and looked forward to the opportunity to guide my students through an analysis of what went wrong and why our results were different than anticipated. Even more exciting was watching my students engage in this process on their own. Recent research on the benefits of learning from errors and a renewed look at the dimensions required for science literacy provide opportunities for agriculture teachers to embrace mistakes in the classroom to cultivate the scientific literacy of our students.

Recent research has highlighted how generating errors benefits the learning process (Metcalfe, 2017). The research suggested that when students make errors, spend time struggling though the errors, receive corrective feedback, and accurately generate correct responses, they are more likely to retain the correct information than when they learn it without making errors at all. Making mistakes helps focus attention on the correct information. As educators, we can capitalize on this research by embracing mistakes and encouraging them as part of the learning process. When we celebrate errors as part of the learning process, we help our students develop a growth mindset in which they look at mistakes as a learning opportunity rather than a measurement of their abilities. This perspective also decreases the stress and negative emotion associated with the stigma of inaccurate responses (Metcalfe, 2017).

Scientific literacy has many definitions which have constantly been evolving, but the National Academies of Sciences Engineering and Medicine (National Academies, 2016) recently published a report on science literacy in which they identified seven dimensions of individual science literacy. Individuals who have developed these seven dimensions are better able to make informed personal decisions, participate in civic decision making, sustain an advanced economy, and recognize the impact of science on culture.

We can develop the scientific literacy of our students within the seven dimensions by learning how to embrace the mistakes that happen within our classrooms. Each of the dimensions for scientific literacy are defined below followed by strategies to develop each dimension in our students. The next time you encounter a "mistake" get excited about the learning opportunity it provides for you and your students, and try implementing some of these strategies to advance their scientific literacy.

Foundational Literacy – using math, reading, and visual literacy to make informed decisions (National Academies, 2016). To develop foundational literacy when a lab doesn't go as expected, students can

- Analyze data tables, graphs, or charts to identify data irregularities.
- Utilize math to make sense of data.
- Read different explanations of a phenomenon and look for alternative explanations.

Content Knowledge – a knowledge of scientific terms, concepts, and facts (National Academies, 2016). Content knowledge can be developed when things go wrong by asking student to

- Check their current understanding of relevant terms, concepts, and facts.
- Identify new content knowledge that may be impacting the unexpected results or change the original hypothesis.
- Use content knowledge to argue why results are accurate or inaccurate.
- Use content knowledge to justify the original or alternative hypothesis.

Additionally, as a teacher, you should provide corrective feedback when the results of a study do not support the concepts or facts the lab was intended to enforce. This corrective feedback will help students recall the correct information in the future instead a creating misinformed assumptions. When presenting accurate information, follow-up by asking students, "How do you think I knew that?" (Metcalfe, 2017, p. 471). While focusing their attention on the correct answer, this question will force students to deeply analyze the phenomenon without being told how to analyze it (Metcalfe, 2017).

Understanding of Scientific Practices – understanding "how scientists do science" (National Academies, 2016, p. 32). This dimension requires student to be able to design and assess studies and evaluate scientific findings. When performing labs, develop your students' understanding of scientific practices by asking them to

- Answer, "why do you think we got these results?"
- Determine if the results make sense.
- Evaluate the design of the procedures.
- Identify what errors may have occurred.
- Establish ways to reduce error.
- Revise their hypothesis.
- Replicate the study.
- Create a revised or new procedure.

Identifying and Judging Appropriate Scientific Expertise – evaluating the expertise of scientists based on their credentials, prestige, publications, and grants. (National Academies, 2016). Student can learn to identify and judge appropriate scientific expertise by

- Analyzing the sources of background information.
- Developing and/or discussing questions to help them make a better assessment of scientific expertise.
- Researching the scientists associated with the concepts and theories.

As a teacher, you may even choose to utilize some background information that comes from more questionable resources and may impact the hypotheses your students make. When the hypotheses are not supported, you may lead them through this analysis of scientific expertise.

Epistemic Knowledge – allows individuals to explain how scientific practices support scientific claims enabling them to recognize the limits of science and determine what results to believe (National Academies, 2016). Developing epistemic knowledge of students can be achieved by asking them to

- Identify limitations of a study or laboratory experiment.
- Explaining how elements of the study lead them to trust or distrust the results.
- Redesign the study to overcome limitations and contribute to more trustworthy results.

Cultural Understanding of Science – appreciating the impact science has had on society (National Academies, 2016). These strategies can help your students develop a cultural understanding of science

- Identifying the connections between scientific findings and societal changes.
- Explaining scientific achievements.
- Consider how society would be different if the inaccurate results from your laboratory were the actual results in the scientific field.

Dispositions and Habits of Mind – dispositions, such as, "inquisitiveness, open-mindedness, a valuing of scientific approach to inquiry, and a commitment to evidence," which affect how individuals interact with science (National Academies, 2016, p. 33). To develop dispositions and habits of mind when a lab doesn't go as expected, students can

- Ask questions.
- Consider different alternatives.
- Analyze evidence.
- Listen to theories from other classmates.

Do not limit your development of scientific literacy dimensions to when things go wrong. While these strategies for developing scientific literacy are focused on when a lab doesn't go as planned, you can implement the same or similar strategies when the lab works great too.

As we prepare our students to leave our classrooms, we want to set them up to be successful members of society. By embracing mistakes that occur in our class laboratories as learning experiences, we model the growth mindset and critical thinking required to learn from the errors our students will encounter in their future. Additionally, as they develop in the seven dimensions of scientific literacy, they will cultivate the skills required to engage with ever advancing science and technologies on a personal, civic, economic, and cultural level. So, the next time your well-planned lab doesn't go as planned, get excited! Embrace the opportunity you have to teach your students to learn from the mistake.

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Multiple Literacies in Agriculture Classrooms

by Dean Powers

Agricultural education has a long history of teaching content in context. Students are exposed to real-world applications of science and technology that, quite literally, feed the world. Across the 3-circle model, students take the content they learn and apply it in various contexts that reflect the work professionals in agriculture engage with every day. This definitely improves agricultural literacy, but, what role does it play in supporting our students' understanding of science? Improving students' scientific literacy is vital to supporting agricultural literacy.

Studies have a shown correlation between agricultural education enrollment and increased STEM achievement. Postsecondary STEM GPAs for agricultural education graduates were higher than those of students not enrolled in agriculture classes (McKim, Velez, & Sorensen, 2017). Working to integrate agriculture curriculum with what students learn in traditional science (Biology, Chemistry, Physics, etc.) classes can continue to support the correlation between ag enrollment and STEM achievement. Additionally, using instructional best practices that science educators use can provide more consistency for students when they're in ag class, leading to more opportunities for collaboration. All of this contributes to the broader goal of improved agricultural and scientific literacy.

Understanding Literacy

I'm analyzing scientific and agricultural literacy through the context of disciplinary literacy for the purposes of this article. Disciplinary literacy refers to the conventions professionals in a particular discipline use to communicate and participate in discourse. Literate practices are the actual strategies and methods professionals use during disciplinary discourse (Houseal, Gillis, Helmsing, & Hutchinson, 2018). It is vital we expose our students to these practices and provide meaningful opportunities to engage with them during class. Finally, a "text" is anything conveying meaning within a discipline.

Science texts extend beyond the traditional definition of written work, too. Peer-reviewed literature or lab reports are what likely come to mind when "science text" comes up in a conversation, and though they are valuable resources, we are doing students a disservice by focusing solely on them. Datasets, diagrams, models, and some informal literature can also be valuable text resources in the classroom. In agriculture, we use texts like labels (for feed, seed, or chemicals), owner's manuals, soil reports, and fact sheets on a regular basis. Students who engage with both scientific and agricultural disciplinary texts, using disciplinary literate practices, will experience greater achievement in both literacies.

The Next Generation Science Standards (NGSS) lay a solid framework for what can be considered essential literate practices in science. Though more broadly defined as "science and engineering practices" (SEPs), they identified as the ways in which scientists communicate and make meaning from texts. SEPs include: analyzing and representing data, making models, using evidence in argument, and designing and conducting investigations. All of these practices can be applied in agriculture classrooms to increase scientific literacy. Overlap between NGSS and the Agriculture, Food, and Natural Resources (AFNR) Standards has been identified (Barrick, Heinert, Myers, Thoron, & Stofer, 2018), and increasing use of SEPs in agriculture classrooms is another avenue into cross-curricular collaboration.

Context Matters

Science education is becoming increasingly focused on teaching through the lens of real-world contexts, similar to historic trends in agricultural education. This is accomplished by challenging students to make sense of phenomena, which enables them to model the work scientists do and connect what they know about the world to the topic at hand. Creating learning opportunities that allow students to think and work like scientists improves achievement across the curriculum. In the context of Career and Technical Education (CTE), focus on sense making also helps prepare students for career opportunities.

Real-world contexts allow students to apply knowledge they already have. Most students can provide superficial explanations of the phenomena I present in my early-field experience lessons based simply on their prior academic or life experience. Activating this background knowledge is another avenue into the content being taught and many people think of learning as a process of connecting what you know to new ideas. If students have some level of familiarity with an idea and can use it in conjunction with SEPs, they can understand core ideas (ie; content) more deeply and know where and how it is appropriate to connect that content to other ideas. This leads to greater depth of learning, as the transcribed class dialog in Figure 1 indicates.

Me: Ok, so (Student 1) just said that she thinks neutering reduces the production of the hormone GnRH. I know group two had some ideas that *disagreed* with this. Could you guys share that with us? {0:01-0:14} **(Follow-up to student)**
Student 2: Well, like, GnRH isn't produced in the testicles, but I think it's like in the brain, but like, it makes sperm so maybe it is reduced?... But that's not true because if you cut its [testicles] off then it won't have any testosterone, and that's what we said was the effect of it. {0:17-0:40}
Me: Ok, let's try to use animal science vocabulary, but that's a great thought! Can someone restate that? {0:41-0:48}
Student 1: Wait, but, like, you never told us we were wrong. But what they said makes sense because only boys make a lot of testosterone, and that's what probably makes them want to mark.... Is that right, or are you still not telling us? {0:48-1:05}
Student 3: No, that is right, because testosterone makes something masculine, and if you remove testosterone you feminize it. ... I don't remember biology, though. But you're right because it makes testosterone in the testicles so if you take them it reduces it, and makes them behave feminine. {1:06-1:36}
Me: So, (Student 3), that's a really great thought, and it looks like we might be coming to a consensus that testosterone is impacted a lot by neutering. So, based on that, I have two questions. First, am I right in thinking that most groups arrived at this conclusion? Second, how could we start to answer the question "why do dogs mark" with this new information? I'll give people a couple seconds to think about this before we share some thoughts. {1:37-2:01}

Figure 1. Dialog transcribed from a task relating to neutering. *Students were using SEPs during this lesson. Students are sense making as they process the evidence they organized. Compare this to the responses you would expect in lecture.*

Primarily, the difference between real-world contexts in science and agriculture classrooms is how students engage with them. In agriculture, the real-world contexts are often problems that need to be solved immediately; if plants in the greenhouse are wilting the morning of the sale, we're not stopping to explain the concept of turgor pressure! In science, students are asked to engage with the teacher, peers, and texts to make sense of phenomena or events that happen in the world. This allows them to engage more deeply in work authentically modeling what scientists do.

Science education is beginning to focus on task-based inquiry lessons to further students' engagement with SEPs, while also promoting whole class discussion and sense making. Agriculture teachers can and should look for ways to implement these tasks in their classrooms. Tasks are classified based on the literate practices they promote. Experimentation tasks focus on designing investigations, but, unlike traditional lab courses, the students are responsible for designing the experimental protocol. Data representation tasks focus on students making choices about how to analyze and represent data; complex datasets are necessary, as this forces students to prioritize what they include. Finally, explanation tasks allow students to engage with texts and other evidence to construct explanations about scientific phenomena. All 3 categories of task place a high cognitive demand on students and allow them to engage with literate practices in the classroom (Cartier, Smith, Stein, & Ross, 2013). Thus, the case can be made that task-based inquiry is a promising route for teachers to take towards increased literacy.

A shift towards sense making in conjunction with literate practices (SEPs) can further support students as they solve problems beyond our classrooms. Agricultural educators should begin to think of the contexts we teach in as intentional instructional choices, rather than something that occurs as a consequence of our content. Granted, in my experience, there's a lot of evidence to suggest that this is the case, but incorporating use of literate practices and task-based inquiry into instructional design can make the contexts we teach in even more impactful for students. In Figure 2, I give some ideas of how to do this in ways aligned with AFNR.

Of particular importance to agricultural education (and, to be fair, CTE in general) is students' ability to use their knowledge and skills beyond the classroom. Contextualizing the situations in which students apply their knowledge and skills in the classroom more closely mirrors the situa-

Pathway	Phenomena	Context	Task Types
Animal Systems	Hormone production in animals changes as a result of contraceptive procedures	Why does my dog stop marking in the house after he was neutered?	Explanation Data Representation
Biotechnology Systems	Organisms show evidence of certain traits when genes are expressed	How is *Bt* activated in GM corn?	Explanation
Environmental Service Systems	Different soil particles (sand, silt, and clay) have different drainage properties	When we add a product like GameSaver to the baseball field, why is it so effective at removing water?	Explanation Experimentation Data Representation
Food Products and Processing Systems	Microorganisms capable of causing illness need specific environmental conditions to grow and reproduce	Why do we refrigerate meats and produce?	Explanation Experimentation Data Representation
Natural Resource Systems	Competition exists in natural systems	How are invasive species able to thrive in forest ecosystems?	Explanation Experimentation Data Representation
Plant Systems	Transpiration rates are influenced by environmental factors like light, temperature, and humidity	Why do my hydrangeas keep wilting in the middle of the day?	Experimentation Data Representation

Figure 2: *Phenomena, contexts, and task suggestions aligned to AFNR Pathways. Contexts can often be framed as questions, which helps students connect them to what they already know about the world.*

tions they would need to apply them in *outside* the classroom. Imagine how much more natural it would feel for a student to explain a hormone issue in a client's cat at a vet's office if they spent time in class engaging with the concept of hormone synthesis through sense making. Contextualizing the science behind agriculture with the real world problems we face will to set our students up for continued success.

Collaboration

Collaboration is also crucial to better contextualizing content. As a student at the University of Connecticut, I've had the opportunity to work with colleagues in science education and get hands-on experience with task based teaching. I've seen students engage in deeper thinking and construct explanations using more complex concepts than I anticipated. Collaborating with colleagues in science is another step agriculture teachers can use to increase agriculture and science learning in classrooms.

There's a lot of teachers (or preservice teachers, like myself) who don't want to see agriculture become another science class, which is a valid stance. However, when people fail to see the value of agricultural education programs, they often argue that the content is not rigorous, or irrelevant. I can't count the number of times I've had to explain to students who hear my major that, yes, we do more than "just milk cows." Collaborating outside of our departments not only allows us to increase our use of instructional practices that promote literacy, but it also lets other stakeholders in schools see that we are taking intentional steps to do that. Our primary focus should be on student success, but collaboration towards this goal can be a great way to quietly promote the necessity and relevance of agricultural education programs to administrators, teachers, and school boards that may not naturally see the value of what we do.

Conclusions

The benefits of more scientifically literate students are numerous. First, science jobs in agriculture often go unfilled. Personally, I was never fully exposed to that sector of agriculture until college. Scientifically literate students, those who can use literate practices well, will be well suited to jobs in scientific field, like research. We need those positions to be filled in order to continue to develop innovative agricultural practices.

Second, scientific literacy will promote increased achievement across the academic curriculum. Students will have skills, like making models or organizing evidence, that can be applied in many contexts and content areas. Not only would these skills continue to promote the STEM achievement correlated to ag enrollment, but, for example, skills like evidence organization and presentation would be vital for success in subjects like language arts or social studies. Ag students have the potential to be some of the highest achieving students in a school if we promote these skills in ag classrooms.

Third, the problem solving and collaboration skills students learned through sense making in the classroom is valuable to success in FFA contests and SAE participation. Students who have been expected to work on teams in the classroom will work well on teams in CDEs and LDEs; given the depth with which they will have engaged in content, they will also have an advantage in content-based contests. Even if you're not as competitive as I am, I think the benefits are obvious. Additionally, students can apply these skills in their SAE projects, making them more employable and improving the overall quality of their projects.

Finally, scientific literacy will promote and support agricultural literacy. Often, agriculture is given an unfair or not factual representation in popular media. Understanding the underlying scientific phenome will allow ag students to help promote a fact-based narrative surrounding American agriculture. In turn, this supports the leadership and advocacy aspects of agricultural education curriculum, further demonstrating the importance of promoting further scientific literacy.

As a preservice teacher, I hear a lot about the "next big thing" in education, and, to be honest, I tend to be skeptical. However, teaching through sense making is one of the rare times I bought in fairly quickly. When I saw the level of engagement and achievement it fostered in the students I implemented it with, I knew it was crucial to my practice as a teacher. Promoting connections between scientific literacy and agricultural literacy, through the use of SEPs and task-based inquiry, is going to be foundational to agricultural education's role in student achievement far into the future.

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