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Incorporating STEM Concepts into Agricultural Education

The Role of STEM Education in 21st Century Agricultural Education

by Harry N. Boone, Jr.

The March-April 2013 issue of *The Agricultural Education Magazine* featured a series of articles on STEM in agricultural education. At that time I made the argument that agricultural education had included STEM components since its inception in the late 19th century. As evidenced from the articles you are about to read you can see that there is agreement with that statement.

In my world the concept of STEM education has exploded since that issue was published (The issue had nothing to do with the changes.). Former West Virginia University President James Clement established five "Mountains of Excellence" for strategic investment of resources. The investment include one hundred new faculty lines. The areas included health disparities in Appalachia, utilization of shale gas, stewardship of water resources, radio astronomy, and STEM education. I had the pleasure of serving on the steering committee for the STEM education initiative. Short term achievements of the initiative include the establishment of the Center for Excellence in STEM Education at West Virginia University and the hiring of four new faculty members. These four individuals will lead WVU's STEM education research initiatives by coordinating research activities among all faculty involved in STEM research endeavors. One of the four individuals, Dr. Jessica Blythe, joined the Agricultural and Extension Education Department in August. The other four faculty members include a Physics Professor, Engineering Education Assistant Professor (also an author for this issue), and a Math Education Assistant Professor. As a result the potential for inter-college and inter-discipline research in STEM education was created.

Dr. Blythe has the opportunity to demonstrate to her colleagues, and the academic community at large, the large amount of STEM topics that are covered in the traditional agricultural education curriculum. From an insider's point of view, we take for granted the large amount of science, technology, engineering and math that the average agricultural education teacher includes in his/her curriculum. While agricultural education has always included significant STEM components, the amount of STEM has increased with the implementation of the CASE curriculum. We not only teach the concepts, we also teach the application of the concepts. I would argue that the application of the concepts not only increases the student's knowledge of the subjects but increases the long-term retention of the information.

At the time agricultural education in the United States was in its infancy, the agriculture industry was considerably different than it is today. Around the turn of the twentieth century, approximately fifty percent of the population was involved in production agriculture. Today that number has dropped to two percent. The two percent that are involved in production agriculture produce 41.9% of the world's corn production, 33% of the world's soybean production, 20.6% of the world's beef and veal production and 17% of the world's milk production. U.S. farmers exports 24% of all agricultural products sold in the world.

How did the United States grow into such a world power in agriculture production? In this author's opinion this achievement has been made possible through the advancement of STEM concepts. Science has given us better varieties, superior yields, more efficient fertilizers, and advanced techniques. Technology has given us better marketing techniques, more efficient communication, better systems of dealing with the weather, computers, etc. Engineers has produced bigger and better equipment and advanced technologies such as farming with Global Positioning Systems. The use of math is central to the entire agricultural production process.

It is impossible for me to tell you what will happen in the next twenty-five to fifty years. Back in the early eighties I knew that the personal computer was going to have an impact, however, I could not predicted the way computers would change our lives. What will be the next "personal computer," "wireless communication," or "satellite position system" that impacts the agriculture industry? You can bet it will combine a knowledge of the agriculture industry with one or more science, technology, engineering and math areas.

Dr. Harry N. Boone, Jr., is a Professor at West Virginia University and Editor of ***The Agricultural Education Magazine.***

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Cover Photo: *Photo courtesy of Lavyne Rada. See complete article on page 10.*
Back Cover: *Photos courtesy of Dexter Knight. Top: Student looks at properties of water during a lab in Ag. Biology; each test tube substance weighs differently and the student used the inquiry lab to determine how each substance would react. Bottom: Student looks at the bottom of two soda cans that were used to determine energy output by two different fuel sources.*

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Can the BUZZ around STEM Education Help Answer Agriculture's Global Challenge?

by Jessica M. Blythe

It has been identified as one of the world's greatest challenges: How can the agricultural industry feed an already hungry global population which is estimated to jump from seven to nine billion by 2050? (STEM Food and Agriculture Council, 2014). This challenge must be met by agriculturalists who can develop new innovative ideas to meet the demand, while conserving our land and water which are essential to agricultural practices.

The importance of agricultural education has never been more evident. It is essential to cultivate a generation of students who have the drive and desire, as well as the knowledge and skills, to pursue answers to the questions that will arise out of this challenge.

It seems that wherever there is a discussion of education nowadays, STEM (Science, Technology, Engineering and Math) drops into the conversation. The buzz around STEM education has become a focus for legislation, funding, and public debate in the various realms of education.

Some see STEM education as the answer to ensure a competent and qualified workforce which will strengthen the American economy. Others are concerned that we as a society are putting too much educational focus on STEM initiatives. Does the focus on STEM education stifle the creative thinking and artistic development of our youth? Are students preparing for jobs in STEM that may not actually exist in the future? No matter your perspectives of STEM, few would negate the positive thread of focused critical thinking and problem solving skills which are evident in the classrooms of each STEM discipline.

It seems that much of the buzz being generated around STEM are the new or improved methods of teaching STEM concepts. These are things that we as agricultural educators have been doing for decades. Problem-based learning: Check. Students getting career experiences outside of schools: Check. Creating close connections between programs and local industries: Check. Giving assignments a 'real-life' context: Check. Focus on college and career readiness: Check.

Educators in non-ag areas are surprised at what is taught in our agricultural curriculums. The idea that we teach science, math, and reading concepts (sometimes all in the same lesson) in our classrooms is often met with disbelief. Emphasizing STEM in agricultural education isn't about changing what we teach or drastically how we teach, but about increasing our communication with other realms of education and using a common language to describe what happens in our programs. Having educators from other content areas become familiar with how agricultural education works will only help to strength our programs and build support within all school communities.

The emphasis on science in agricultural education has been a part of educational reform since the US industrial revolution and it is time to also emphasize the other individual 'TEM disciplines as well. Continuing to emphasizing STEM education initiatives within our existing agricultural education frameworks can provide that next generation of agriculturalists who are able to make strong connections between the STEM disciplines and the agricultural industries. The goal of preparing young minds with a broad range of scientific and engineering skills, with the technological and mathematical ability to manage the large scale programs can help the agricultural industry meet the challenges.

In this issue you will find a broad array of articles offering different perspectives on the possibilities of STEM education in agricultural education. Many of the articles offer ideas from an agricultural education perspective, however you will also find some articles that offer perspectives from educators outside of agriculture who use their areas of specialization to provide a unique perspectives and ideas to our classrooms.

Enjoy this issue!

Dr. Jessica Blythe, the March-April Theme Editor, is an Assistant Professor in the Department of Agricultural and Extension Education and WVU Center for Excellence in STEM Education at West Virginia University.

THEME ARTICLE

AGSTEM Interdisciplinary Collaboration: Building Bridges from Subject to Subject to Enhance College and Career Readiness

by Catherine A. DiBenedetto

Our world is challenged with the great task to feed more than nine billion people by the year 2050. Who will take responsibility for leading the effort to create sustainable solutions for our future? No one person or group of people can be solely responsible for such an enormous task. Engaging a broad audience of people to become part of the solution is the answer. A diverse group of people from various disciplines, and of all ages, need to come to the table to create solutions that are developed through collective thinking and cross disciplinary communication.

Interdisciplinary education programs are beginning to appear in the curriculum mainly in academia for graduate level students. The University of Florida has created Challenge 2050, a certificate program for undergraduate students. The program has redesigned the college experience by incorporating teamwork, multidisciplinary studies, and entrepreneurial thinking practices. Students are challenged to develop solutions to the problem rather than simply focusing on the problem. The students develop teamwork, critical thinking, problem solving, and communication skills that are necessary for successful entry into college and careers of the 21st century. In the near future, additional universities will continue to develop similar programs that our high school students will need to be prepared to enter.

Our future leaders are our current high school students. Are these students being prepared to accept the challenges they will face when they enter college and the workplace of the 21st century? Throughout the school day, as our current students move from class to class, are they provided with opportunities to connect the skills and concepts taught in one class to another? Are students challenged by experiences throughout the curriculum that explore real world problems? Are students encouraged to develop a sense of social responsibility?

> AGSTEM interdisciplinary collaborations can produce a “win-win” scenario for everyone.

Interdisciplinary learning experiences can assist in bridging the gap between knowledge acquisitions from subject to subject and transfer application into real world experiences. As teachers design their daily lesson plans, do they consider how the skills and concepts they teach relate to what their students are learning in other subjects? Do administrators encourage and provide time for interdisciplinary collaboration among teachers in their schools?

If the common goal of the school is to prepare students to be college and career ready, how are teachers, administrators, parents, industry leaders, and the local community working together to support this goal? Evidence suggests that students are not prepared to enter the 21st century workplace (NRC, 2000). Teachers and industry leaders have voiced concern for college and career preparedness of students as they graduate high school and enter college and/or careers. Teachers indicate that nearly 40% of their students will need remedial training to successfully enter college or a career (MetLife, 2011). Industry leaders indicate that students are not prepared to enter the workforce (Carnevale, Smith, & Melton, 2011). Skills including problem solving, critical thinking, communication, teamwork, initiative, self-direction, and grit/perseverance are required for students to be successful in the 21st century workplace (Duckworth, Peterson, Matthews, & Kelly, 2007). As teachers, how can we support the needs of our students while preparing them to be college and career ready?

Science, technology, engineering, and math (STEM) has become a critical component to discussions in education and industry. STEM integration is not a new concept. Educating our students in STEM subjects has become fundamental to providing them with a foundation for successful employment in the 21st century. If the school system works together, positive outcomes will follow for all involved. Reflect for a moment on the African proverb "it takes a village to raise a child." It takes the efforts of several teachers within a school system to prepare a student to be college and career ready. The STEM initiative has provided rich prospects for collaboration among teachers. Interdisciplinary collaboration can assist in developing social responsibility and attaining common goals.

Broadly defined, agriculture is the science, art, and business of "farming." Agriculture is an applied science. Science is knowledge formed by a process of continuous inquiry. Many aspects of STEM are naturally highlighted and integrated into the curriculum through the three circle model of the School-based Agricultural Education Program. Agricultural education teachers should reach out to a diverse group of teachers to design and plan interdisciplinary lessons that will engage all students.

Why should I collaborate?

Collaboration between and among STEM and AGED teachers can assist in building an environment where supportive individuals work towards a common goal. For example, positive student outcomes arise as real world examples and experiences are offered when students learn about and can apply the skills and concepts they learn in their science classes to their supervised agricultural experience projects (SAEP) in their agricultural education program. Students become aware of a broader set of experiences that can be applied to a variety of diverse careers that are STEM related.

Diversity of thought is an important aspect to create solutions to real world problems. Annual school-wide goals need to be met. Working together will help achieve those goals and prepare students to be both college and career ready as they enter the 21st century and face great challenges. Those challenges will require the creation of solutions to real world problems.

How can I begin to collaborate?

Identify a team of teachers or a partner that you would like to collaborate. Start small and plan a few brainstorming sessions to plan engaging lessons, evaluate student work, and reflect on your current teaching practices. Determine the areas within your curriculum that would be most beneficial for STEM collaboration. Consider how you are currently integrating STEM into your curriculum. What concepts would you like to enhance? What are your areas of strength? Where do you need assistance to support an idea you may not feel comfortable to teach? What are the goals of your school district? What are the specific needs of your students? What resources do you need to enhance student learning in STEM?

With your interdisciplinary team, design a lesson plan to integrate STEM skills and concepts that focuses on a set of curriculum standards, an essential question, and the lesson objectives. Consider team teaching or co-teaching as a method to utilize the strengths of the teachers. Determine the teaching methods and instructional strategies that are most appropriate for the content of the lesson. Think with the end in mind. What is the instructional goal of the lesson? What learning outcomes do you expect for your students? How will you guide your students throughout the learning process? What academic knowledge and technical skills will your students know, understand, and be able to do as a result of the lesson?

Keep in mind, collaboration can be challenging. It can be difficult to plan and teach interdisciplinary units of instruction. Collaborative efforts will take commitment and dedication among all of the members involved to assure success. Plan for reflection time after the experience and brainstorm new ideas and design new lessons. Build upon your successes and work to improve areas of weakness.

What's in it for me?

Collaboration can provide an opportunity for a division of tasks among the team members. A collaborative environment can assist with classroom management and provide time to exchange ideas and learn new teaching methods and strategies. Reflective teaching practices can be very rewarding and refreshing. How often do you seem to get stuck interacting with the same group of people? Collaboration provides rich opportunities for you to expand your circle of colleagues. In addition, you are gaining new knowledge to help increase your ability to be an effective teacher.

Collaboration with other teachers also provides an opportunity to utilize shared resources. Funding for laboratory equipment, tools, materials and technology can drain a department budget very quickly. Sharing resources and developing joint plans for purchasing education materials can increase opportunities for student learning and decrease overall spending.

What about my students?

Concepts and skills learned in one class relate to another. STEM integration through interdisciplinary collaborative efforts can help to reinforce important concepts from all subjects and assist in making learning relevant to students. Thus, helping to prepare students to solve the problems they will face when they enter the real world.

As students become college and career ready they will be learning and experiencing many of the skills that are required to be successful in the 21st century workplace which include: teamwork, responsibility, communication, social skills, self-discipline, self-esteem, problem solving, and critical thinking skills. Students will begin to erode the concern perceived by industry leaders for their lack of preparedness into the 21st century workplace. Our future leaders will be better equipped to join in the efforts to create solutions for our world challenge to feed more than nine billion people by 2050.

What are the potential outcomes?

Although the STEM initiative has posed some challenges for education and in general, collaboration can be challenging, those challenges should be viewed as prospects for developing innovative educational experiences for our students. When we face great challenges, we must work together to create sustainable solutions to reach our goals. Interdisciplinary collaboration through AGSTEM can assist in preparing students to be college and career ready. Students will develop the skills and be offered opportunities to engage in interdisciplinary education that will give them the momentum to persevere in the face of adversity throughout their lives.

Work with the teachers in your school to gain new knowledge and plan engaging STEM lessons that will excite and motivate your students. Include your administration to help reach the shared goals of the curriculum, program, school, and district. Include parents to create partnerships that will encourage involvement in school activities and student learning. Reach out to the community for support and to determine industry needs for career readiness, as you prepare your students to enter the 21st century workplace. When carefully designed and executed, interdisciplinary collaboration is an instructional strategy that can help achieve success for a diverse group of individuals. AGSTEM interdisciplinary collaborations can produce a "win-win" scenario for everyone, where educational gaps are closed and bridges from subject to subject are built and maintained.

A student examining eggs that are in the process of hatching. (Photo courtesy of Lavyne Rada - see complete article on page 10)

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Finding Ag-STEM in the Real World – Connecting to Community Resources

by Kathryn A. Stofer

As professionals work to re-emphasize the connections among agriculture and the foundational STEM (science, technology, engineering, and mathematics) disciplines, we don't want to overlook the vast learning resources that exist outside the traditional classroom. In the United States, the amount of time spent learning STEM in a formal school setting is a tiny fraction of our overall waking hours; the school year lasts only nine months, each of those months there are at least eight weekend days, and even on school days, the hours we spend in school and especially on science are limited (Falk & Dierking, 2010). We also know that students learn STEM more readily when the concepts are integrated with their everyday experiences.

The resources to which I refer may be called non-formal, informal, out-of-school, lifelong, or free-choice learning resources, depending on your position in education (Stofer, 2015). Whatever they are called, thinking broadly about the ways we can make use of opportunities in our surrounding communities will contribute to our overall goals of truly connected Ag-STEM. Many of these resources may not explicitly sell themselves as Ag-STEM, but if we look at them creatively and with new perspectives, it is easy to see how they can complement our formal curricula. And while funding for field trips may be limited, suggesting your students visit with their families or friends for extra credit or even for a homework assignment can accomplish similar purposes of getting them out into the real world and making those connections.

If you are searching for these resources, one starting point is your local tourism board or visitor and convention bureau. These groups compile resources for people who are visiting or new to town and aim to showcase all the area has to offer. As a result, their listings are diverse and comprise a number of sectors including fine arts or entertainment, which neither STEM nor agricultural educators may normally consider as prospective learning opportunities for their disciplines. However, just as there are several movies and documentaries about science that you could relate to agriculture, there could also be theatrical performances or art shows that relate as well.

Tourism and visitor bureaus or chambers of commerce will also list other partners, such as sports leagues, that may offer other ideas such as lists of athletic facilities, events, fields, parks, and equipment like rock climbing walls that can be used to demonstrate physics or mathematics or engineering. Touring a baseball stadium with natural grass, for example, can lead to discussions about care and maintenance and even the requirements for grasses based on the physics of the game. Other listings may include events such as speaking engagements or farmer's markets which could be related to your Ag-STEM curricula. Last year, Bill Nye, the Science Guy, was a featured speaker at the performing arts center for the University of Florida. Festivals, fairs, and markets such as farmers markets could even just be a place to get your students outside and themselves thinking beyond the walls of the classroom.

Visitor bureaus also may not be aware of or think about what educators may view as a learning situation, so their lists may only be a starting point. One major resource that tourism boards may not consider is Extension. Extension is a partnership among universities and state and federal governments bringing research results to your life ("Extension", 2015). Your local county Extension events may not make it to the tourism board listings, yet they are obvious sources of Ag-STEM learning opportunities inside and outside the classroom. Extension may offer canning classes, where pressure and temperature and food safety are covered; gardening classes involving plants, insects, and chemistry of pesticides and herbicides; or green cleaning, talking about water systems, land use, chemistry, and the environment, to name just a few. Extension agents often can even come to your classroom to offer their workshops. Their offices and web sites also have a wealth of resources connecting to real-world research.

Professional associations for free-choice learning venues and providers often list their member organizations online, with the ability to filter by location. One list that includes many museum organizations is Museum Market: http://www.museum-market.com/AssocList.htm. Check out the Association of Science-Technology Centers; Association of Living History, Agriculture, and Farm Museums; Association of Zoos and Aquaria; American Public Gardens Association; and American Association for Botanical Gardens and Arboreta in particular. Don't forget to check listings of ongoing and special events for the organizations near you. Even if they may not be appropriate timing for a field trip, you may be able to visit yourself and get ideas for context for your educational activities or meet guest speakers for your classes, as well as brush up on your own knowledge.

Don't forget to tap your own social networks, either. Those "recommendations" by Twitter and Facebook may sometimes seem annoying, but they can often uncover organizations, especially at the state or national level, that you can look into for ideas. As Laura Hasselquist said in the March/April 2013 issue of this magazine, "Use your resources – Work Smarter, Not Harder" (p. 7). Ask your friends and family where they go in the area. Think of all the places they might visit for day or residential camps, or field trips or family outings for enrichment and "edutainment."

So you've found these resources, but now what? Maybe your science museum doesn't list any exhibits on "agriculture" or the farm nearby doesn't tell you about the "STEM" that farmers use. The S1057 Multistate Project team, headed by researchers in the Ag-STEM Education Research Lab at the University of Florida, http://aec.ifas.ufl.edu/ag-stem-lab/, is working to make explicit connections between AFNR Career Cluster standards (National Council for Agricultural Education, 2009) and the new Next Generation Science Standards (NGSS Lead States, 2013), to which many science centers or STEM institutions connect their content. However, it is fairly straightforward to find topics that are related at a broader level. For instance, for the AFNR Career Cluster Animal Systems, look for content related to live animals, wildlife, habitats, people, or nutrition. For Biotechnology, you might find exhibits about microbiology, molecular biology, or biochemistry. Many science centers have hands-on laboratory activities on DNA that they contextualize with human biology, but with a little introduction in the classroom, you could relate to plant disease and pathology. Environmental Service Systems and Natural Resource systems cover climate change and chemistry, as well as basic backgrounds on the Earth's "spheres" such as water in the hydrosphere, air in the atmosphere, or even energy cycles. These clusters and of course, Plant Systems, connect especially well to parks, farms, and gardens, as you can ask students to investigate the systems at work. Agribusiness systems connects to math across many science and engineering content areas; with a little planning, one can guide students to think about even exhibits that cover very basic content such as water and how it might be privatized, publicly-controlled, or a mix of the two, and what the implications for agribusinesses are. Finally, for the Power, Structural, and Technical Cluster, exhibits on engineering and energy, unusual museums such as local Waterworks or Waste Management or power plant tours, and even history museums can be places to look for free-choice learning opportunities and resources around Ag-STEM.

How can teachers help their students recognize these connections in the context of limited time and resources? Make finding the connections between agriculture and STEM topics part of the assignment that students must complete, leaving it open-ended how they do so. As Catherine Shoulders said about incorporating STEM in the classroom, "Students should be knowledge contributors rather than just knowledge receivers" (2013, p. 15). Students could be challenged to find three topics related to agriculture on a visit to a science center, or they could be asked to explicitly reflect on how destruction of ecosystems, covered in a recent class lesson, was happening in a local park. On the flip side, take your students to a farm and ask them to discover how the farmers use STEM in their operations. Reach out to the local venues you might have the students visit and ask them to work with you to adapt some of their existing pre- and post-visit lessons, either adding STEM to agriculture curricula or vice versa. You will be helping them provide more resources for other teachers as well. Ask the venues about other teacher opportunities and workshops they have; often they have an annual night that teachers can visit and preview for free, or workshops that explicitly provide teachers with lessons as part of the take-away. These, too, are chances for you to partner with them in ways you can both benefit to re-emphasize STEM connections to agriculture.

Finally, be sure to properly prepare your students for any field trip. Publications from organizations such as the National Science Teachers' Association have resources on field trip planning, which are available for individual article purchase. You could also reach out to researchers at your

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STEM Education Beyond the Classroom

by Lavyne Rada

Does carbon dioxide improve plant germination? Are GE-EPDs more accurate than EPDs? Why do birds fly in formation? Which are more feed efficient: steers or heifers? Does a wetland remove contaminants from water?

As I walked through the Minnesota State AgriScience Fair in February, there was an excited hum from students as they explained their research findings to judges, advisors, and other FFA members. Regardless of the awards received by these students that afternoon, one thing was clear to me: each one of these AgriScience Fair participants understood how to question and develop a sound plan to answer that question by using and applying the scientific method, and they also skillfully demonstrated the ability to write and speak about their personal experiences. Because of the AgriScience Fair, more than 125 middle and high school FFA members used their experiences in the classroom to explore topics of interest to truly experience the learning process by directing and controlling their learning.

Agricultural education programs have taken agricultural content and made it relevant to students. Science, technology, engineering and math (STEM) have long been taught and applied in the agricultural education curriculum, but with the spotlight on STEM education, this integration in the classroom has been highlighted more strategically. According to the 2013-2014 Federal Carl Perkins Database and the Minnesota Department of Education, nearly 15% of Minnesota's agricultural education students received science credit for an agricultural education course. In Minnesota, students can earn chemistry, physics and science elective credit in agricultural education courses that meet the standards. However, STEM education is also occurring in FFA activities. For example, the AgriScience Fair students demonstrated the skills and knowledge of STEM concepts, explained their understanding the rigorous content, and applied it to their own relevant situation for their research.

> Students are applying STEM concepts while developing leadership skills needed to be the leaders of tomorrow.

Agricultural education teachers have taken STEM education beyond the classroom as we do with every topic. Agricultural education has long been grounded by the three-circle Venn diagram displaying the integral relationship between classroom instruction, experiential learning through Supervised Agricultural Experiences (SAEs), and leadership development through the National FFA Organization. The STEM instruction occurring in agricultural education classrooms across the United States is expanding into STEM experiences outside of the classroom through SAEs and in FFA as a result. By encouraging our students to integrate STEM learning into all areas of agricultural education, we can create a well-rounded, career-ready learner.

As a former agricultural educator, I know the desire to connect classroom experiences to SAE and FFA so students are able to gain hands-on career skills and understand the relevance of classroom content. The AgriScience Fair was one way I was able to see the science concepts taught in a class being applied as the students designed and completed a research experience. Students also used a variety of technology and engineering principles to design the experiment, gather data, and display their results to the audience. The data gathered was then analyzed using math principles so it could either support or disprove the student's hypothesis. This is just one example of how agricultural education students are applying STEM concepts in FFA, but AgriScience research projects were also one of my favorite ways as a teacher to incorporate inquiry-based thinking and allow students to demonstrate their understanding of a topic and the scientific method.

Career development events (CDEs) in FFA also have many examples of how STEM concepts are reinforced. Whether it is Agricultural Technology and Mechanical Systems, Food Science and Technology, Milk Quality and Products, Meats Evaluation and Technology or Floriculture, science, technology, engineering and math are used in all of these CDEs and more! Members in the Agricultural Communications event are asked to use a variety of technology to share key messages with an audience on radio, television, print, or on a website. Likewise, Agricultural Technology and Mechanical Systems competitors use technology, engineering and math throughout the event to solve problems related to machinery, electrical systems, construction, and much more. Members in the Nursery/Landscape event apply engineering and math skills as they calculate the needs to execute a landscape plan while maintaining a profit. Members in the Veterinary Science event apply a variety of biology and chemistry scientific principles as they prepare to work with a variety of animals while also applying mathematical concepts including conversions, dose calculations, and invoices. These are just a few examples of how FFA is continuing to provide relevant experiences to members as they apply STEM concepts with Career Development Events.

The SAE program is another way for students to apply STEM concepts. Some entrepreneurship SAEs allows students to engineer a product to sell or provide a service while another expands a student's ability to apply math principles to tracking the income and expenses of their business. One student's placement SAE applies the science concepts they learned while they work for the local greenhouse and identifies the nutritional deficiency appearing on the plants while another student uses the drone technology to scout and diagnose threats in a corn field. A student with a research SAE is analyzing the effects of organic and inorganic crops on the local watershed while another student is researching the opinions in his community about genetically-modified-organisms being labeled on food packaging. A student with an exploratory SAE is researching and completing a job shadow at General Mills with a food scientist learning about how new food products are developed and marketed while another student explores the options for renewable energy sources for her high school. All of these students have experiential learning experiences related to STEM concepts.


A student preparing to analyze the effects of organic and inorganic crops on the local watershed.

Additionally, these students also have the opportunity to share their competence and expertise of these concepts through FFA exhibits and award applications. More than 480 students displayed their SAE through an exhibit at the Minnesota State Fair in 2014. Greenhand, Chapter, State and American Degrees allow students to demonstrate their abilities and knowledge while earning their degree and applying math skills as finances are tracked. More than 4.29 million dollars were earned and 3.15 million dollars were invested through SAEs in Minnesota in 2014. Proficiency award applications specifically allow students to describe specialized skills they have developed through their SAE. Degrees and Proficiency Awards acknowledge the students who have excelled in developing career skills, which include many STEM concepts.

Agricultural Education has always taken core academic content and shown relevant applications to students. STEM concepts have been treated no different. Opportunities in FFA have continued to support agricultural education by providing experiences for students to continue to develop STEM-related skills in and outside of the classroom. In Minnesota, nearly half of the FFA members attended a regional or state leadership conference. The United States Department of Education quotes President Obama stating, "…Leadership tomorrow depends on how we educate our students today-especially in science, technology, engineering and math" (www.ed.gov/stem). Agricultural education is providing the rigor and relevance related to STEM. Through FFA, students are applying STEM concepts while also developing the leadership skills needed to be the leaders of tomorrow.

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THEME ARTICLE

Taking Advantage of the STEM in Agriscience

by Steven "Boot" Chumbley

The editorial of the April 2013 issue of *The Agriculture Education Magazine* started off with title, *Agriculture: The Original STEM*. Dr. Harry Boone reinforced the benefit of science, technology, engineering and mathematics (STEM) being taught within the agriscience classroom, as long as it was presented in the context of real world examples. In the two years since that publication we have seen more and more agriculture science teachers turn their focus to the integration and teaching of STEM principles. This is important as the demand for motivated high school graduates to enter postsecondary STEM fields is at its highest, but student interest and readiness has been declining (Rothwell, 2014). As an integral part of agricultural education, the FFA student leadership organization is an integral component in motivating students to learn a variety of skills at many different levels (Phipps & Osborne, 1988; Gruis, 2006). This leaves agricultural science programs with the opportunity to offer and positively motivate students to pursue STEM based education.

We consistently hear from proponents of STEM integration that it is not about adding any more to the curriculum, but about highlighting the science that is already there. While that may be easy to say, it is not always readily apparent how or in what way to accentuate the science within our agriculture lessons. As Dr. Boone pointed out, we must find ways to integrate these concepts in the context of real world examples. It should not be forced or shoe-horned in a way that it interferes with the original lesson. So what are some of the ways that we can naturally integrate STEM into the agriculture education curriculum, while still completing all the other tasks we must complete when coordinating a successful agriculture program?

Evaluate How We Are Teaching

The benefit of project-based learning, which increases conceptual understanding of science and promotes positive attitudes towards learning science and contextualized science education (Rivet & Krajcik, 2008), is a promising teaching technique that should be used to support future leaders in agriscience. An example of such a lesson is the building of an efficient tower or "load bearing" wall. Such a project challenges students to construct a structure that can support a designated load. In the project students deal with the same problems faced by engineers in the real world. They are given specific design parameters that their structure must comply with (height, weight, time limit, etc.). While completing this laboratory exercise, participants must consider building materials, method of assembly and production costs. Their structure must perform a specific task. The parameters of this task may include supporting a specific weight (usually using an item commonly found within the classroom or spanning a certain distance while maintaining strength (emphasizing strength to weight ratios).

There are a number of resources to assist teachers in developing this teaching skill. This can include participating in the Curriculum for Science Education (CASE) institutes, professional development at NAAE and state agriculture teacher annual meetings and collaboration with other faculty who have experience with this teaching method. The National Science Teachers Association (nsta.org) has multiple free resources for developing laboratory and problem based lessons. Teachers who challenge students with lab-based lessons foster the critical thinking skills that ultimately benefit students in other parts of their educational career.

Make it a Contest

Many states are accentuating the STEM concepts within career development events (CDE). This ranges from identifying the most up to date technology within a specific CDE's content area (agronomy contestants identifying differences in farming mechanizations or veterinary science students identifying surgical tools). The state of New Mexico requires students who compete in the agricultural technology and mechanical systems CDE to complete a twenty question agriculture construction math test, in combination with the other requirements of that event. The same is true for the veterinary science contest, where students must determine proper dosages and health science based conversions. We can naturally reinforce these STEM concepts by continuing to develop specific components within our career development events.

In addition to the National FFA Agriscience fair, most states offer an agriculture science fair that further supports students learning of STEM concepts. The agriscience fair involves students from grades 7-12 in multiple divisions to test scientific hypothesis and develop their findings for presentation, either as a team or as individuals. Coordination with science and math faculty can help teachers and students to develop creative projects that reinforce STEM within real world contexts. I would also encourage agriscience teachers to reach out to university faculty to assist in the formulation of projects and possible support. The key to success in this area is taking advantage of the resources that are available based upon your school and community.

One way to get students interested in beginning a science fair project is to introduce all your students to the benefits of such projects. Begin with a project that involves the whole class. Examples of this include developing a hypothesis and monitoring growth rates of animals on the school farm based on the protein percentages of their feed. Another example can include measuring germination rates of seeds based upon various types of growing media. After involvement in an all class project, students can be assigned smaller groups to develop their own project, slowly helping them to become more comfortable taking more responsibility when conducting an agriscience project.

Seek Out Support

An obstacle to STEM integration agriculture science teachers often run into is having enough resources to offer innovative, problem based STEM activities to their students. One way to obtain these resources is through grants and strategic partnerships. As part of the 2015 budget, the Department of Education has set out over $110 million for STEM Innovative Networks. This program will award grants to school districts in partnership with colleges and other regional partners to transform STEM teaching and learning by accelerating the adoption of practices in P-12 education that help to increase the number students who seek out and are well-prepared for postsecondary education and careers in STEM fields.

Teachers are encouraged to seek out funding from their school district in support of initiatives to integrate STEM in the agriculture classroom. There are a number of outside sources that teachers can look to as well to seek funding. One such resource is the company STEMfinity (www.stemfinity.com). They offer project based learning STEM curriculum along with grants and grant writing support. I know several agriculture science teachers who have been successful receiving grants that they found through websites like www.stemgrants.com.

As agriculture educators, we are used to developing partnerships and relationships with community and business leaders. I would encourage teachers to take this entrepreneurial spirit when developing resources for STEM integration. Teachers can partner with local universities, museums and industry to increase students learning of technology. Guest lectures from these various partnerships can add to students understanding and interest in STEM within agriculture. Invite a local dealer to bring some of their newest products in and explain to students the advancements in technology and their impact on precision agriculture. To help students better understand the science behind GMOs, invite a local seed rep to discuss this topic and how they benefit production agriculture.

Dual Enrollment Courses

One strategic partnership that has shown to help students develop STEM skills as well as increase college success is the participation in dual enrollment courses. Dual enrollment (sometimes referred to as concurrent enrollment) allows high school students to enroll dually in their normal high school class and a corresponding college course. These programs are offered in various formats and in multiple classes. There are number of colleges that offer various models of agriculture dual enrollment programs. Louisiana State University recently started offering such courses, Murray State University in Kentucky offers multiple courses through their Racer Academy, while the University of Tennessee at Martin offers courses in agriculture engineering and animal science, to name just a few. In New Mexico, we offer six different dual enrolment courses in the areas of plant science, animal science and agriculture mechanics. These courses are offered in a hybrid model where students complete lab activities and daily instruction within their high school agriculture classroom, but perform all tests, quizzes and other assessments online with university faculty. This can be an innovative way to establish strategic partnerships as well as challenge students with increased science and math integration within their agriculture courses. The added benefit of this program is that they are also receiving college credit.

Taking Advantage

Agriscience is a robust and appealing curriculum that employs both formal and informal learning opportunities for students. It has shown to be beneficial in students' learning of STEM concepts and in helping students to transfer these skills to practical real world applications. It is excit-

continued on page 19

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STEM Education through Funds of Knowledge: Creating Bridges between Formal and Informal Resources in the Classroom

by Joel Alejandro Mejia & Amy Wilson-Lopez

Students encounter a clash of microcultures when they view the world of science and the world of their everyday lives differently. Lee (1999) explained that students bring with them their own way to see and interpret the world. These worldviews are representative of their social and cultural environments and personal experiences. The task of reconciling different and incompatible ideas create a greater challenge for underrepresented students who try to make sense of dissimilar worldviews, such as the worldviews they are presented with at home and the worldviews they are presented with in STEM classrooms (Lee, 1999; Lee, 2001). This discrepancy becomes a challenge not only for students but also for teachers who may fail to recognize the knowledge and experiences that underrepresented students bring to the classroom (Lee, 2001).

To counter this disconnection between students' everyday lives and the instruction they receive in their STEM classrooms, the National Research Council (2009) argued that STEM instruction "needs to connect with students' own interests and experiences" (p. 2-4). Creating a bridge between different formal resources (e.g., engineering design processes) and informal resources (everyday knowledge) is an important step toward encouraging students to enter and remain in STEM. However, a cultural border crossing is created when the norms, values, beliefs, or actions of the students do not align with those norms, values, beliefs, or actions of the scientific community (Aikenhead & Jegede, 1999). Thus, examining students' out-of-school experiences is very important in order to create a bridge that aligns the students' cultural worldviews with classrooms practices.

> Teachers can draw from the students' knowledge by asking the students to reflect on their experiences.

Funds of Knowledge and STEM Education

Students may encounter different conflicts when their everyday life world does not connect to the science classroom world. Culture and social interactions influence the cognitive processes of students and their sense of belonging and identity (Aschbacher, Li & Roth, 2010). Jegede and Aikenhead (1999) argued that learning is "a social process mediated by culture and is significant in accomplishing the construction of meaning in new situations" (p. 45). Students bring with them their own way to see and interpret the world. These worldviews are representative of their social and cultural environments and personal experiences.

In previous educational literature, the construct of "funds of knowledge" has served as a bridge that connects students' household and peer bodies of knowledge with the formal bodies of knowledge learned in school. Authors have used the term "funds of knowledge" to describe the cultural knowledge and skills present in students' households and communities, which include knowledge related to agriculture, health, workplace skills, ethics, financial management, and marketing among others (Moll et al., 1992).

The work of Moll, Amanti, Neff, & Gonzalez (1992) provided evidence that students can successfully bring their funds of knowledge to the classroom and use them as powerful learning tools. The framework used in the funds of knowledge project by Moll et al., provided a venue for students to bring their cultural and linguistic practices to the classroom (Moll & Arnot-Hopffer, 2005). Moreover, the work on funds of knowledge opened new research venues where home and community practices were joined with educational paradigms in meaningful ways to increase learning and access for those who have been historically marginalized.

Previous studies have suggested that, when funds of knowledge are incorporated into science curricula, students are more engaged and often develop richer understandings of scientific concepts. For example, Barton and Tan (2009) and Moje et al., (2004) demonstrated that underrepresented students' experiences with work outside of the home, with work inside of the home, with popular culture, with health (e.g., managing diets), with international travel, and with the environment were all generative platforms on which to base engaging, socially relevant science instruction.

In a study performed by Mejia et al., (2014) with Latino adolescents in a rural area in the Western U.S.A., a funds of knowledge approach was used to investigate how funds of knowledge of historically underrepresented students may enhance engineering design thinking. The adolescents that participated in the study had previously worked in farming activities and came from working class families. Some of the participants worked in a dairy farm at the time of the study. The objective of the study was to determine how adolescents used their funds of knowledge as they engaged in a community-based engineering design problem. The study concluded that the adolescents could make connections between their everyday knowledge and use it to enhance their engineering designs.

Participants integrated knowledge and discourses drawn from different spaces (e.g., household, communities of practice, classroom). The adolescents drew selectively and strategically from two opposing categories to open new alternatives, and what seemed to be oppositional categories were used to generate new knowledge, new discourse, and new forms of literacy. Overall, the adolescents' funds of knowledge in this study were significant for the brainstorming of solution, development of solutions, and evaluating and implementing their solutions to the community-based project. The adolescents transformed their learning environment by fostering new hybrid spaces that included a better participation role, motivation, and an effort to provide a social good. They were able to expose themselves to an engineering practice that integrated their everyday knowledge. The study suggested that Latino students, although profoundly underrepresented in engineering, bring a wealth of knowledge and experiences that can be relevant to engineering design thinking and practice.

Funds of Knowledge and Classroom Implications

The studies mentioned in the previous section can be used to inform future research related to funds of knowledge as well as classroom practices. For instance, instructors could ask questions to the students at the beginning of the school year regarding their interests, their parents' jobs, transnational movements, or their involvement with the community. These questions can be used as a form of inquiry where teachers use the students' responses as a basis for teaching STEM. Teachers can look into the different resources of the students and create their own innovative instructional strategies that draw from those resources.

One example of how teachers can draw from the students' funds of knowledge is to ask the students to reflect on their experiences in the farm (especially with rural students) or gardening while discussing relevant engineering, math, or science concepts. For instance, if the students wanted to design a better harvesting method, teachers could guide students through reflecting on their experiences with farming such as the tools used, appropriate materials, and harvesting processes in general. Then, the teacher would use this discussion as a basis for teaching scientific and engineering principles related to brainstorming, ethical considerations, evaluating solutions, information gathering, design, manufacturing, processing, and trade-offs among others. Students could describe why specific designs are used for specific products as opposed to other available designs that serve the same purpose. The students can identify similarities and differences about their designs and list the trade-offs encountered in their attempt to implement and improve a specific design. This activity would allow students to engage in engineering-related practices and the instructor would be able to combine formal and informal resources in an effort to promote engineering crosscutting activities, habits of mind, and dispositions. Moreover, these practices are necessary to promote more inclusive STEM practices that value the cultural, social, and everyday life experiences of the students, especially underrepresented students.

Students may avoid constructing scientific knowledge or align only with scientific knowledge that does not interfere with their everyday life experiences (Aikenhead & Jegede, 1999). The conflicts arising from the microcultural clash between the science classroom and the students' everyday life do not help students since they must learn how to deal with cognitive conflicts – especially when the transition between the science world and the everyday life world is not addressed by their teacher. Therefore, the ideology of "science for all" is not attainable unless a culturally sensitive curriculum embraces the students' everyday life experiences and the social context of learning science and engineering (Lee, 1999). For instance, teachers could at least acknowledge and seek to understand students' worldviews and allow them to voice them in class while also teaching students the principles that are accepted by the scientific community.

Although a funds of knowledge approach may be beneficial for students, the strategies mentioned in this article are not meant to suggest that funds of knowledge frameworks are sufficient for preparing students for STEM careers. However, this approach indicates that instructors can engage in activities that are more inviting to students, particularly students from marginalized groups whose experiences, practices, and interests are usually not valued in schools (Gonzalez & Moll, 2005). Students possess bodies of knowledge, skills, and practices that are directly relevant to STEM, and teachers can use funds of knowledge as an instrument to initiate conversations that help students engage in STEM.

> Instructors can engage in activities that are more inviting to students, particularly students from marginalized groups.

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THEME ARTICLE

Renewable Energy: A New Vehicle for STEM in the Agriculture Classroom

by Catherine Shoulders

When students, teachers, the general public, and even agriculturalists are asked to name components of the agriculture industry, they rarely identify energy as a prominent aspect. Livestock, crops, and mechanics come to mind most readily. Agricultural issues often focus on these components as well, with genetically modified organisms, pesticide usage, and GPS farming being some of the more prominently debated developments. But within the broad realms of environmental stewardship and management of natural resources, both very crucial components to every agricultural industry, is energy management. Energy can be a costly aspect of an agricultural business, both monetarily and to the business' public image. As energy costs continue to rise, electricity bills can cut deeply into the profits of poultry producers, greenhouse growers, dairy producers, and the like. Electricity usage's contribution to environmental degradation via fracking and global warming suggests that reducing dependence on fossil fuels is viewed positively by consumers. Students entering agricultural careers should graduate understanding not just how electricity works, but also how it can be best managed for a business' success.

A less-widely-debated but ever-more-prevalent issue in agriculture is the use of renewable energy. The most common renewable energy technologies focus on harvesting from solar, wind, and water sources. As students learn about electricity, you can enhance their understanding of STEM principles, instill in them a value for energy sustainability, and better prepare them for careers in any agricultural industry by including in their learning experiences renewable energy components.

Teaching students about renewable energy is easier said than done for most agriculture teachers; very few have learned about renewables in their own teacher education programs, and with little time for personal education, expecting a teacher to educate students about solar energy installations is a bit unrealistic. Fortunately, there exists numerous resources designed to assist you in providing meaningful renewable energy learning experiences to your students. Who knows, you may even learn enough to consider installing renewable energy technology at your own home! This article is designed to give you a bare-bones crash course in renewable energy and share with you a list of the resources you can use to teach your students about renewable energy. Most are freely available, some only require a computer and Internet connection, but all are designed to help you incorporate STEM via renewable energy in your classroom with minimal preparation!

> Incorporating renewable energy education in to your classes can propel your electricity lessons into the future.

Renewable Energy – The Basics

To renewable energy experts, whom you are likely to ask for additional resources and information, there are some basic pieces of information that indicate whether you have any understanding of renewable energy. To put this in, for example, equine science terms, you can spot a rookie a mile away if they try to mount a horse from the right side. Here are some basic tips to get you past the point of "Renewable Energy Rookie":

1. Renewable energy is just that, renewable. It is not "alternative energy," which suggests that it shouldn't be the norm. Renewable energy experts feel that it should be, and potentially will be, mainstream in the near future.

2. Solar energy is the most feasible renewable energy technology in the US. It's not the most efficient (that would be micro-hydro), but it is the most readily available in all locations and the one with technology appropriate for most locations.

3. When you refer to a solar "panel," you're probably talking about a module. A solar module is made up of small cells that convert solar energy into DC electricity. This process is called the photovoltaic effect, and so solar energy technologies are frequently called photovoltaics. Numerous modules wired together are called an array.

4. As mentioned earlier, micro-hydro (that is, using a turbine to produce electricity via running water in a stream or river) is the most effective method of renewable energy production. This is because while solar arrays can only collect when the sun is out and wind turbines only spin when the wind is blowing, moving water is always moving, allowing electricity to be generated 24/7. However, it's not the most-widely feasible because it's only available to those that have running water sources on their properties.

5. For many locations, current electricity costs, upfront installation costs, and relatively limited incentives make renewable energy more expensive than energy produced from fossil fuels. However, as these components change, renewable energy will become more affordable for a greater number of people and businesses. In the past five years, it already has and this trend is projected to continue.

6. Generally, there are four reasons people are interested in installing renewable energy technologies: economics (Will it save me money?), independence (Can I have electricity when the grid goes down or if I'm in a remote location?), environmental stewardship (Can I reduce my environmental impact?), and innovation (Can I be the first on my block to install this?). Meeting each of these goals requires a different installation configuration, even within the same type of energy source. For example, a solar array built for independence would need a battery back-up, which makes the system more costly and negates any environmental benefit because of the production of the batteries. An on-grid system without a battery backup would be most cost-effective and environmentally friendly, but would leave you without electricity in the event of a power outage.

> Students entering agricultural careers should not just how electricity works, but also how it can be best managed for a business' success.

Renewable Energy Education Resources

Now that you're familiar with the basics, let's focus on how you can teach your students about renewable energy. The following list shares teacher-friendly renewable energy resources, including the components which I, as a teacher educator, find to be most useful for the parameters and limitations common to the teaching profession:

1. University of Arkansas' REAP- One of my two favorite resources is the Renewable Energy Analysis Project (REAP), run by Yours Truly at the University of Arkansas. If you aren't in Arkansas, don't ignore this one; REAP strives to develop custom distance-based learning experiences to meet the learning goals of each group – FOR FREE! The project allows your students to conduct experiments remotely with on-campus renewable energy technology, and then view the results, often in real-time. If you're in the area, feel free to plan a trip to bring your students to REAP for some hands-on learning experiences. The stations allow learners to manipulate renewable energy components to determine the impact of those manipulations on electricity generation. The project includes both stationary components housed in agricultural settings, including an on-grid solar array, an off-grid solar array, a wind turbine powering a pond aerator, and an integrated solar/wind station that transports water from a well, and mobile stations, including four Mobile Energy Efficiency Units and six solar ovens. Learn more about REAP at http://reap.bumpers-college.edu.

2. AgEnergy: Agricultural Energy Curriculum – This is my other favorite resource, primarily because it offers renewable energy curriculum for agricultural contexts. Hosted entirely on a website, 15 educational modules introduce students to energy basics, conservation, renewables, solar, geothermal, wind, hydropower, bioenergy, biofuels, and anaerobic digesters, all for agricultural settings. The modules include estimated required time, learning objectives aligned with Bloom's Taxonomy, an overview of topics covered, PowerPoints, student handouts, and quizzes. The curriculum developers are currently working on aligning each lesson with Common Core, Common Career and Technical Core, and Agricultural, Food, and Natural Resources content standards so

you will be able to share with administrators exactly how the modules fit in to your existing curriculum. To access these complete and ready-to-use resources, visit www.agenergyia.org.

3. ATEEC Interactive Learning Lab's Learning Stations – Iowa's Advanced Technology Environmental and Energy Center has pulled together a fantastic set of short videos about energy. Learning stations focus on biodiesel, green energy, solar power, and wind energy. Videos are hosted through YouTube, and most are under 10 minutes. Check them out at http://ateeclab.org/learning-stations/.

4. Solar Energy International's Introduction to Renewable Energy Course - For your own personal education, enroll in RE100, a free online course that focuses on "the basics of renewable energy – including where it is found, how we can harvest it for use in our homes and how it can help ease pressures on the environment" (Solar Energy International, para. 1). Solar Energy International is a leading expert in renewable energy education, accredited by the Interstate Renewable Energy Council. Registration is free, as is the RE100 course. Other more advanced courses cost, but you can gain a thorough understanding of renewables (at least enough to teach your students) through the free course. Enroll at http://solarenergytraining.org.

5. KidWind – If you're looking for renewable energy kits that will enable your students to conduct their own experiments, I recommend KidWind, which specializes in renewable energy education kits for the classroom. They have fully inclusive, off-the-shelf kits for creating solar towns, experimenting with wind turbine fins, building sail cars, constructing solar fountains, and the list goes on. They even host an internet-based wind turbine challenge in which your students can compete. If you're still not sure what to teach, they've got professional development events to introduce you to the lab materials and associated lessons. Start shopping for your next lab at www.kidwind.org.

Each of these resources can assist you in incorporating science (How is renewable energy harvested?), technology (Let's record the difference in electricity generation between the module blocking UV wavelengths and the control via the real-time data output!), engineering (Which fin design produces electricity at the slowest wind speed?), and math (How many modules would need to be installed to produce 100% of your home's electricity?) into your electricity education plans. As agricultural businesses focus more on responsible energy management, please use these resources to prepare your students to improve the electricity usage of their future employers. Incorporating renewable energy education into your classes can propel your electricity lessons into the future, encouraging in your students a value for sustainability and innovation!

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Taking Advantage of the STEM...

(continued from page 9)

ing to see where agricultural science courses are headed and the path that is before us as educators. We have so many tools in front of us to be leaders in the future of STEM education. Take advantage of what is available and seek out new ways to improve the lives of our students.

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Seeing and Leveraging the Mathematics in Agriculture Education

by Matthew Campbell

There has been much attention in policy, mainstream media, and in education settings around STEM as a way to categorize a set of disciplines; all positioned as important in today's world. This attention is built on the notion that the fields of science, technology, engineering, and mathematics provide numerous opportunities for the integration of ideas; provide meaningful, robust, and context-rich settings for learning; and help prepare the current generation of students for college and careers. While a categorization such as STEM offers many opportunities and affordances, a 2014 report from the National Academy of Sciences on STEM integration in K-12 education (Honey, Pearson, & Schweingruber, 2014) highlights the challenges and shortfalls. This is due, in part, to the emerging critique that STEM is too broad of a category for instructional decisions, for educational goals, and for careers (Kurtzleben, 2014).

With the attempt to see how the fields of science, technology, engineering, and mathematics are similar and how spaces can be created in which students engage with ideas across disciplines, the opportunity to and need for acknowledging the distinctions in those disciplines is often lost. Mathematics often gets short shift in STEM, mainly in the way the discipline is often positioned in inauthentic ways and due to the lack of tangible outcomes in mathematics for students as a result of integrated experiences (Honey, Pearson, & Schweingruber, 2014). Opportunities for students to complete calculations or use formulas and procedures that typically dominate the mathematics curriculum do not adequately serve as innovative or beneficial mathematics experiences, though such a perspective is a common pitfall for STEM activities and discussions.

Agriculture education serves as a prime example of a space in which students develop and work in context and at the intersection of multiple disciplines. Agriculture educators, as much as if not more than any other educator, do their work at the intersection of the STEM disciplines (and then some). This, like the category of STEM itself, provides many affordances as well as challenges. As a mathematics educator by training and experience, I come to you as a bit of an outsider. I write this article, though, to provide the perspective and specific examples of how you can "see and leverage" the mathematics in your agriculture classes and activities and do so in authentic and meaningful ways. This is important because many of you, as agriculture educators, have concrete responsibilities regarding mathematics education goals either in your collaboration with mathematics educator colleagues, your own concurrent role as a mathematics educator, or the way in which you are tasked with integrating mathematics content into your agriculture classes.

A Focus on Mathematical Practice

One product of the past thirty years of mathematics reform (driven, in part, by the work of the National Council of Teachers of Mathematics) has been the attention to the core proficiencies that embody mathematical thinking and reasoning. Attention to problem solving, communication, use of mathematical representations, and mathematical justification provided a more concrete focus beyond the more vague dichotomy set up between "procedural fluency" and "conceptual understanding." The Common Core State Standards for Mathematics (CCSSM; National Governors Association Center for Best Practices, & Council of Chief State School Officers, 2010) provide the next iteration of these ideas with a set of "Standards for Mathematical Practice" (see Figure 1). These mathematical practices are considered to be the central aspect of the standards and the key to achieving more ambitious and equitable aims for mathematics education in schools. They provide a framework for the types of mathematical proficiencies that students should be able to demonstrate and also provide

1. Make sense of problems and persevere in solving them
2. Reason abstractly and quantitatively
3. Construct viable arguments and critique the reasoning of others
4. Model with mathematics
5. Use appropriate tools strategically
6. Attend to precision
7. Look for and make use of structure
8. Look for and express regularity in repeated reasoning

Figure 1: CCSSM Standards for Mathematical Practice

6.RP. Ratio and Proportional Relationships

Understand ratio concepts and use ratio reasoning to solve problems.

1. Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities.

3. Use ratio and rate reasoning to solve real-world and mathematical problems

   C. Find a percent of a quantities as a rate per 100; solve problems involving finding the whole, given a part and the percent

Figure 2: Examples of CCSSM standards addressing understanding and use of ratio

a lens through which to understand the mathematical content standards. However, these mathematical practices are often overlooked, thus decreasing the likelihood of meaningful changes in mathematics education and of positive and productive gains of student performance and outcomes. Regardless of whether or not your state has adopted the CCSSM as its K-12 mathematics standards, the attention to these mathematical practices and their connection to mathematical content is key for all educators with any role in students' experiences with mathematics.

The Case of Mathematical Modeling

While all of the mathematical practices listed above and many of the mathematical content standards outlined in the CCSSM are relevant, mathematical modeling serves as a good focus in thinking about seeing and leveraging the mathematics in agricultural contexts. According to the CCSSM, "modeling is the process of choosing and using appropriate mathematics and statistics to analyze empirical situations, to understand them better, and to improve decisions" (p. 72). Modeling is a mathematical practice that has intersections with scientific and engineering practices that are also outlined in new standards, but that also has its own characteristics. The contexts that arise in agriculture education provide the meaningful phenomena and relationships to be modeled with mathematics while also providing the opportunity to focus on particular mathematics content. The task, then, is to have the awareness to explicitly draw attention to the mathematical practices and ideas that are a part of the work of an agriculture education setting.

As an example, students may consider the impact of soil composition on crops in terms of size, yield, or other metrics of quality. While this is an agriculture problem and also possibly an object of scientific inquiry (including scientific modeling), such an activity is also an opportunity to think pointedly about how students engage with mathematical practices, such as modeling, and how important mathematical ideas emerge. In such a situation, students would need to think about ways to quantify characteristics of soil, using appropriate mathematical tools. For instance, students might use ratios or percentages to represent the amount of a particular element or substance in the soil or to quantify the hydration of the soil, which requires an understanding of ratios as a particular kind of mathematical relationship—one that has connections to percentages (see Figure 2).

Understanding ratios also has a role in students determining, for instance, how much fertilizer or water to add to a certain volume of soil in order to obtain particular ratios. Sim-

A-REI. Reasoning with Equations and Inequalities

Represent and solve equations and inequalities graphically

11. Explain why the x-coordinates of the points where the graphs of the equations y = f(x) and y = g(x) intersect are the solutions of the equation f(x) = g(x)l find the solutions approximately, e.g., using technology to graph the functions, make tables of values, or find successive approximations. Include cases where f(x) and/or g(x) are linear, polynomial, ration, absolute value, exponential, and logarithmic function.

F-IF. Interpreting Functions

Analyze functions using different representations

7. Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases.

   e. Graph exponential and logarithmic functions, showing intercepts and end behavior, and trigonometric functions, showing period, midline, and amplitude.

Figure 3: Examples of CCSSM standards highlighting attention to logarithmic functions

ply plugging numbers into a given formula does not effectively do this work, as students are best equipped for these problems through an understanding of ratio. This includes knowing and articulating when and why particular relationships can be represented as a ratio and what that ratio means when converted to a percent or to an equivalent ratio. Conversely, engaging with these types of problems in the agriculture education setting can serve as the way to further develop these kinds of mathematical ideas, even beyond their targeted grade. Students might also consider the pH of the soil. As a measure, pH is not a ratio but is determined using a logarithmic function, which is a family of functions with which students must engage throughout high school mathematics and which represents a particular kind of nonlinear relationship between two variables frequently used in science and engineering (see Figure 3).

S-ID. Interpreting Categorical and Quantitative Data

Summarize, represent, and interpret data on two categorical and quantitative variables

6. Represent data on two quantitative variables on a scatter plot, and describe how the variables are related.
    a. Fit a function to the data; use functions fitted to data to solve problems in the context of the data. Use given functions or choose a function suggested by the context. Emphasize linear, quadratic, and exponential models.
    b. Informally assess the fit of a function by plotting and analyzing residuals.
    c. Fit a linear function for a scatter plot that suggests a linear association.

Interpret linear models

7. Interpret the slope (rate of change) and the intercept (constant term) of a linear model in the context of the data.
8. Compute (using technology) and interpret the correlation coefficient of a linear fit.
9. Distinguish between correlation and causation.

Figure 4: Examples of CCSSM standards addressing modeling and interpreting data

In this situation, students may look to better understand a variable of interest (e.g., yield of crops) as it related to another variable (e.g., pH of soil). This, too, involves many opportunities to focus on the practice of mathematical modeling as well as particular mathematics content (see Figure 4). For instance, a student might collect data on the yield of crops and plot those data relative to the pH of the soil in which those crops were grown, creating a scatterplot. Students will use that scatterplot to make informal claims about if the two variables are related and, if so, the way in which they are related (e.g., linear relationship, exponential relationship). Based on those inferences, students can use technology to fit a function to the data, to assess the fit of that function, and to use the function to solve problems and make predictions about the relationship. Students should consider the limitations of the function they have fit to their data, including the presence of any error and the risks of assuming that the function will hold even beyond the bounds of the data they collected (i.e. extrapolation). Students can also consider the difference between correlation and causation and the implications for the kinds of claims they can make. Through this kind of work, students use and further develop important mathematical ideas around statistics and data analysis. Furthermore, the ideas used and developed through such an experience have the potential to reinforce students' understanding of functions (linear and nonlinear), their features (such as rate of change), and their representations (such as graphs and equations)—resulting in even broader mathematical benefits.

The mathematical work highlighted across this example extends far beyond the calculation of various ratios or percentages, the use of given formulas, the plotting of data, and the calculation of a line of best fit. Through mathematical modeling, students make purposeful decisions about the mathematical tools they use to make sense of, represent, and solve problems related to a phenomenon—drawing on and further

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Teaching Irrigation with the Integrated STEM Approach

by Eric Stubbs

As editor Dr. Boone wrote in the first STEM-themed *Agricultural Education Magazine* issue, agriculture is the original STEM. When STEM concepts are learned in the context of applied agricultural practices, students can't help but see the relevance and value of science, technology, engineering, and mathematics. This article will discuss how to teach irrigation through the latest research-based framework of STEM education.

According the National Academy of Engineering and the National Research Council (2014), what separates STEM education from other approaches is that it links the separate disciplines together through a real-world context. They use the term "integrated STEM education" to emphasize this interdisciplinary component. The approach helps students answer questions like how does science help create new technology? Or how do new technologies affect science? – and so on with the other STEM disciplines. The framework for integrated STEM (see Figure 1) education outlines the elements educators should consider in planning, implementing, and assessing outcomes.

Nature and Scope of Integration

In the real-world context of irrigation systems, several disciplines are linked. Physics is the basic scientific discipline that explores motion and fluids. The two key mathematical concepts involve measurements of flow (motion of a fluid) in gallons per minute and pressure in pounds per square inch. These concepts are applied in order to engineer a working irrigation system – first on paper, and then in real life. Use of irrigation is also connected to horticulture and its knowledge related to plant needs and evapotranspiration. Of course, students must also learn about irrigation technology.

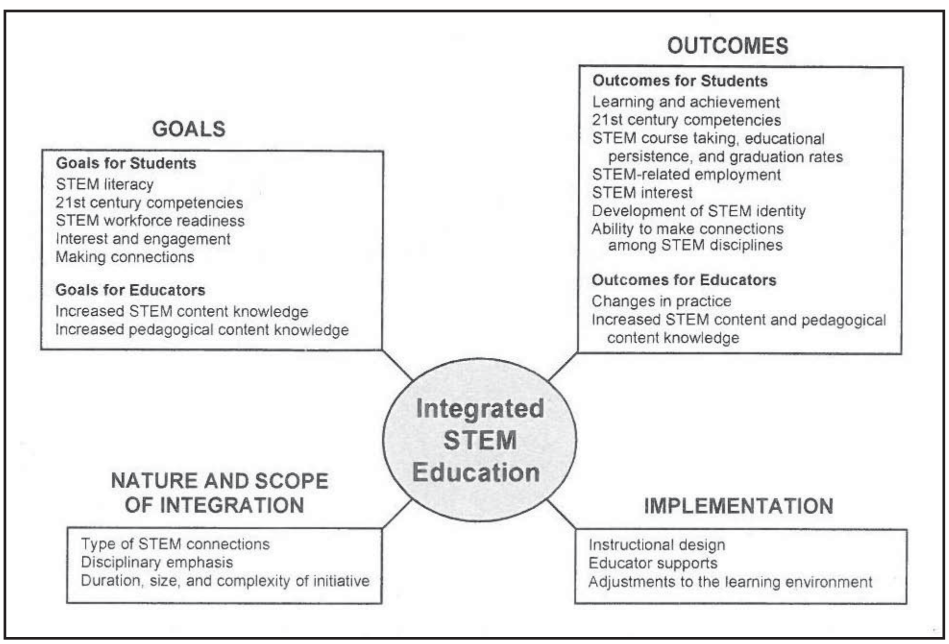

Figure 4: Integrated STEM Education

Technologies themselves often provide fertile ground for connecting disciplines and increasing the depth of instruction. For instance, backflow preventers provide a simple mechanical solution to the possibility of contaminants flowing from irrigation pipes back into other pipes that supply potable water. Yet backflow preventers took years of effort by scientists and engineers to develop! See O'Brien (2013) for a link that describes the history of these devices from 1840 to present. Solenoids and controllers could connect to units on electricity, and rain sensors have been developed to increase efficiency.

To design a working irrigation system, students must first gather information. They will need to know the area to be irrigated and the type of sprinkler or emitter. While flow can be measured with a bucket and a stopwatch, pressure gauge technology is needed to measure pressure. Then students can use equations to ensure a functional irrigation design: flow from the water source must be greater than the sum of all the flows of sprinklers or emitters. They must also estimate pressure loss due to the diameter and length of piping to ensure the sprinklers receive the required water pressure. An excellent, free source of information about these mathematical requirements can be found at www.irrigationtutorials.com.

Goals

The goals of 21st century competencies and workforce readiness are vital to continued growth in agricultural and economic production. Design and maintaining irrigation systems provides students with both intellectual and physical abilities that could be useful in the workforce. Competence in setting and adjusting an irrigation controller may seem like a small accomplishment, yet it is a transferrable skill that increases students' confidences and abilities to interact with other technologies.

Furthermore, by linking scientific disciplines, mathematics, technology, and engineering, students should develop an improved overall understanding of how these seemingly isolated fields interact in real-world contexts. This addresses the goal of increasing STEM literacy. Students must understand that each discipline has knowledge that informs the others. If agricultural engineers hadn't applied knowledge from physics and mathematics to create irrigation technologies, imagine the world we would live in!

In the end, the nature and scope of integration will depend on the length of the unit and the teacher's preference. By making explicit connections between the STEM disciplines, agriculture, and practical applications, teachers may be able to improve students' interest and learning in STEM. Even within the topic of irrigation, possibilities for connecting disciplines, technology, and real life applications are nearly endless.

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Seeing and Leveraging the Mathematics... *(Continued from page22)*

developing understanding of underlying mathematics concepts (such as ratio, relationships between quantitative variables, the formulation and use of a function of best fit). The key in any setting geared toward making progress toward mathematical goals is to realize and highlight that those mathematical practices are just as valuable, if not more so, than the computational and procedural skills involved in the work.

Conclusion

As a mathematics educator I defer to you, the agriculture educator, to consider the contexts that are appropriate to use mathematics and engage in mathematical practices. I acknowledge, too, that this work must be considered in relation to content and practice standards in agriculture and in the other STEM disciplines. My hope is that the ideas used to motivate this article, the highlighting of the idea of mathematical practices (specifically modeling), and the examples given above serve as part of a foundation to see and leverage the specifically mathematical aspects of the work you do with students. Perhaps it serves as a way to put a name to the work you already do, or it serves to inform how you can make more explicit mathematical connections with your students. It is through more detailed and purposeful connections to the mathematics discipline that the potential of work at the intersection of science, technology, engineering, and mathematics (and agriculture) can be fully realized.

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AG ED – A Century Strong and Carrying on in Global STEM Leadership

by Jessica M. Jones

When you think back to when you were in school, which teacher stands out in your mind as the individual who sparked and maintained your interest in inquiry, critical thinking, and problem-solving while integrating real-world concepts and applications? If you answered, "My agriculture teacher," then you are among the tens of millions of students nationwide who have been in an agricultural education course where science, technology, engineering, mathematics, reading, writing, public speaking, and other curriculum were embedded in your experience.

Not only may you have had these learning experiences as an agricultural education student, but you may find these experiences to be common place for agricultural education students in your classes today. Phipps, Osborne, Dyer and Ball (2008) stated, "Over 800,000 students are enrolled in agricultural education instructional programs offered in grades seven through adult in 50 states and three U.S. territories." Over the past century, agricultural education teachers have been engaging students in rigorous, relevant and meaningful scholarship to prepare them for life and the global workplace. Moreover, these same agricultural educators have served as a strong alliance of astounding instructors who are more than advocates, innovators, and leaders, but practitioners in the fields of science, technology, engineering and mathematics.

As cited in R. L. Lynch (1994), the 1914 writings of Joseph S. Taylor emphasized that vocational-industrial teachers must know the technique of the trade to command the respect of employers and foremen. The National Society for the Promotion of Industrial Education (NSPIE, 1914), the forerunners of the 1917 Smith-Hughes Act, the original federal vocational education act, concluded that:

Trade teachers should first of all be masters of their trade. To be qualified to teach their trade they must have lived it; from this trade experience they bring skill and intimate acquaintance with the best practices of its every branch (p. 12).

For decades, agricultural education teachers have been living out and bringing to life to their students the content of agriculture through the incorporation of scientific principles, technical pursuits, engineering feats, and mathematical bases. As agricultural education covers a diverse spectrum of information, these "best practices" are strategies implored by agricultural educators to identify, differentiate, educate and inspire society's youth to strive for excellence and purpose in and out of the classroom. According to the National Association of Agricultural Educators (NAAE) (2015):

Agricultural education teaches students about agriculture, food and natural resources. Through these subjects, agricultural educators teach students a wide variety of skills, including science, math, communications, leadership, management and technology. Agricultural education is delivered through three interconnected components: Classroom or laboratory instruction, experiential learning, and leadership education.

Furthermore, there's a national call and a global challenge to educators from President Obama to articulate a vision for the future of STEM education, "…Leadership tomorrow depends on how we educate our students today – especially in science, technology, engineering and math." In September 2010, President Obama launched the "Educate to Innovate" campaign as a part of the Change the Equation initiative devoted to improving the quality of STEM education in the United States. The initiative would rally the government, the business community, teachers, parents, and students to provide a means of enhancement to the learning environment that nourishes and accelerates student growth and student leadership of the 21st century economy. President Obama's initiative would help students flourish in STEM realms, while applying their ingenuity to product formation, research, design, manufacturing, and marketing, by increasing the workforce and economic prosperity.

Under the "Educate to Innovate" campaign, the President's fiscal year 2015 budget has several investments designed to improve teaching and learning in STEM subjects for teachers and students in schools in the United States. Key elements of the budget proposal include $170 million in new funding to aid in training teachers by transforming STEM teaching and learning in P-12 education. More so, as stated by the United States Department of Education, a committee on STEM education (CoSTEM) comprised of 13 partner agencies, including the United States Department of Agriculture and the

United States Department of Education would:

Facilitate a cohesive national strategy, with new and repurposed funds, to reorganize STEM education programs and increase the impact of federal investments in five areas: P-12 STEM instruction; increasing sustaining public and youth engagement with STEM; improving the STEM experience of undergraduate students; better serving groups historically underrepresented in STEM fields; and designing graduate education for tomorrow's STEM workforce.

However lofty these goals may sound to current society, these same goals have been over a century a realization that have come to fruition through agricultural education. Take for example I serve as a National Agriscience Teacher Ambassador for DuPont USA, Lab-Aids, Inc., NAAE, and the National FFA. As an ambassador, I facilitate professional development workshops at local, state, regional, and national science conferences, in addition to, at the DuPont Agriscience Institute at the National FFA Convention and NAAE Convention, helping other agriculture teachers learn how to teach more effectively. The National Agriscience Teacher Ambassador Academy (NATAA) has over 10 years successfully cultivated agriscience and inquiry-based learning in agricultural education. The Academy trains agriculture teachers on how to enhance the science that is already present in agriculture and develop students as problem-solvers and thinkers through inquiry-based teaching methods (A. Smith, personal communication, March 13, 2015). There have been over 300 teachers and 49 states that have been involved with the Academy since its inception and it continues to evolve and grow with the needs of its teachers and societal changes.

The core of the case as to how agricultural education has been able to for over 100 years address the pedagogical needs of its teachers, as well as, the workplace readiness needs of the industry is by understanding the structure of the agricultural education program. Phipps and Osborne (1988) exclaimed, "The predominant model for organizing instruction in agricultural education involves the interrelationships between three major concepts: classroom and laboratory instruction, supervised agricultural experience, and agricultural youth organization participation." Further, Talbert, Vaughn, and Croom (2006) exerted:

Classroom and laboratory instruction are those activities that provide learning experiences within the confines of a school facility. These classroom activities are characterized by learning activities defined by an agriculture teacher and presented to students using formal instruction methods such as lecture, demonstration, guided and independent practice, review, and assessment. Instructional content includes agricultural mechanics, animal science, horticulture, agricultural production and biotechnology (p. 110).

As outlined in the "Educate to Innovate" campaign, the programs involved in the initiative would identify and implement effective approaches for improving STEM teaching and learning; facilitate the dissemination and adoption of effective STEM instructional practices nationwide; and promote STEM education experiences that prioritize hands-on learning to increase student engagement, interest, and achievement in the STEM fields. But, these STEM programs are already carried out in agricultural education through its instructional structure and professional development activities; it's just not promoted as such.

In a career that productively trains students to become analysts, biochemists, biologists, electricians, engineers, farmers, machinists, managers, physiologists, ranchers, scientists, teachers, veterinarians, and the list goes on coupled with a projected agricultural occupation growth rate increase of 10% to 30% and STEM occupation growth rate of 20% to 60% over the next five years, agricultural education is perfectly aligned to continue educating students to be at the top of the pack by demonstrating excellence in STEM education for today and tomorrow. Agricultural education must continue to forge boldly forward, making great strides in the fields of science, technology, engineering and mathematics through instruction, professional development, and experiential engagement as we have provided a century strong of global STEM leadership through agriculture and are prepared to continue to provide leadership for a century more.

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Finding Ag-STEM in the Real World... ***(continued from page 9)***

local university, to your local public library, or to the article authors themselves and ask if they can help you obtain a copy of their article. There are more and more research-based resources available that are not yet free or "open-access" formats, of which teachers can most easily take advantage. If you ask for these resources, however, it makes people aware of the demand for them.

Some general tips are to make sure your students know what to expect on the field trip, and make sure they know how to complete the activities you may ask them to complete. This means most likely that you will need to take time in class to teach students how to observe objects that they will encounter and that you want them to consider. However, you must also take time as well to cover basic information such as how to find their chaperone and what to do if they get lost, and even where to find the restrooms and when you will eat lunch. Meeting students' needs for these things first will make it easier for them to focus on the educational activities (Hobgood and Richardson, n.d).

If you are going to visit an established venue such as a museum, their web sites often list field trip planning guides that help you to deal with logistics. They also list pre- and post-visit activities, though these may be listed with the programs or in a separate area of the web site from the overall logistics, such as under the Education department. One great example of this with both general planning and logistics and specific exhibit lesson information is on the Smithsonian Field Trips web site: http://smithsonianeducation.org/educators/field_trips/field_trips.html. With a little creative thinking and careful planning, you and your students will soon see that Ag-STEM is all around you!

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