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Emphasizing the Science, Technology, Engineering, and Math (STEM) in Agricultural Extension[1]

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Summary

The UF/IFAS Extension Roadmap for 2013–2023 (University of Florida, 2013; a.k.a. the "Roadmap") lists several 'High-Priority Initiatives' related to heightened public awareness of agricultural topics, including food systems and the environment (Initiative 1, Priority 3, a.k.a. "Ag Awareness"), water issues (Initiative 2, Priority 3), environmental stewardship (Initiative 3, Priority 3), community capacity development (Initiative 4, Priority 3), and resources for decision-making (Initiative 6, Priority 3). The Roadmap also considers STEM opportunities for youth as a "Super Issue" representing a "broad societal challenge requiring cross-programmatic efforts" (University of Florida, 2013). These programs provide opportunities to highlight the research basis of Extension work and to empower the public to make use of IFAS research findings as informed consumers and decision-makers. Highlighting the research behind Extension raises the profile of *agriscience* in the public eye. Greater public awareness allows the current Ag-STEM workforce to capitalize on the connections among agricultural, scientific, and technical expertise, while preparing our future workforce.

One way to encourage these connections is by structuring Extension programming to build participant practices while they learn content. That is, the Extension agent works to empower participants to gather, share, and analyze information, mimicking the production and application of knowledge in professional agriscience and Ag-STEM practice. This process helps participants apply practices from the program to future problems. This EDIS document guides Extension agents wishing to emphasize the connections of applied agricultural knowledge, basic science, and technology in their programming. Our examples are drawn from Horticulture but can be adapted to other disciplines.

Figure 1. Participants learning farm machinery safety integrate agricultural and STEM learning in real-world context.
Credits: UF/IFAS

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STEM and Extension

STEM is an acronym for *science, technology, engineering,* and *math.* Educators, researchers, policymakers, and employers are currently motivated to improve the knowledge and practices of the STEM workforce, as well as the general public, in these areas. Each group, and even individual projects or programs, may define STEM differently (Gerlach, 2012). For example, some groups may integrate one or more of the constituent subjects, such as a blended science and math course or a math and engineering course. Some teachers may team-teach classes on separate subjects, trying to coordinate curricula while retaining recognized courses. Other models may try to fully-integrate all STEM topics in a single course. Despite this variation in implementation, all STEM subjects share a systematic approach to problem solving, including observing, understanding current knowledge, defining the problem, thinking creatively, testing, and iteratively refining all of the steps to reach the end goal. The product of the approach may be knowledge (science or math) as well as physical or conceptual objects (engineering or technology).

STEM is part of Ag-STEM for Extension in the agricultural sciences. Ag-STEM Extension requires emphasizing to clientele the research- and design-based knowledge generated from the underlying traditions: not only agriculture but also science, technology, engineering, and mathematics. Land Grant and Sea Grant Extension services, in particular, are likely to emphasize the STEM connections in agricultural contexts. In US public formal education, these subjects traditionally have been taught separately, though often in parallel (Hillison, 1996).

In Extension, our purpose is outreach, to share the knowledge or products created through Ag-STEM research and design by universities and government agencies. Increasingly, research output involves participation of industry partners and even the public. In Ag-Extension, finding effective solutions to agricultural issues, especially in urban areas, increasingly involves working with clientele to solve problems jointly. Therefore, emphasizing the connections of STEM to agricultural problems through Ag-Extension programming can help our public audiences comprehend the problem-solving system underlying the content. The goal is to provide public audiences with self-confidence and practices in STEM, preparing them to be more engaged in the problem-solving process for the challenges ahead.

How People Learn

First let us consider how adults generally learn. Although K-12 schools in the United States have only recently embraced more self-directed, learner-centered strategies, adult education professionals have long recognized the need to structure educational programs to draw on adults' interests and capacities for self-improvement (Knowles, Holton, & Swanson, 2005). The content of Extension programming, while centered on stakeholder needs, often can be better tailored to adults' and other out-of-school learners' motivations and interests. Extension programs that incorporate these strategies to meet the needs of adult learners can increase the value and enjoyment for participants. For insight, Extension professionals can look to principles of *andragogy*, or strategies for self-directed adult learning. We will consider six principles in the context of Horticulture Extension programming.

Specific Facilitation Strategies

The style of presentation described in this document to address adult learners is a learned skill that can be improved with practice. An example to illustrate some specific strategies when planning and delivering programs in this manner may be helpful.

The first principle states participants need to know *what learning will occur, why it is important,* and *how the learning will occur* (Knowles et al., 2005). A Horticulture agent wishing to conduct a workshop on the management of a common type of ornamental plant pest could address this principle early when advertising the program. A workshop by the authors, "Scales and Mealybugs, One of Florida's Primary Types of Ornamental Plant Pests—Identifying, Eliminating, and Preventing the Problem in a Hands-on Workshop," illustrates the first principle. The title emphasizes the *what*: identifying, eliminating, and preventing this pest group; the *how*: via a hands-on workshop; and the *why*: because these insects are among Florida's most pervasive, expensive, or otherwise problematic threats to landscape plants. Throughout the program itself, the agent can reiterate these *what*, *why*, and *how* components.

Second, organizing the workshop for participants to address each step of the problem-solving process, in a structured manner (i.e., within an agenda), addresses several principles outlined by Knowles et al. (2005). It sets up the learning around a problem to be solved (Orientation), provides real-world context for the learning to the participant (Relevance), and draws on learners' own needs for learning (Motivation). The agent can pitch the program at an appropriate level for participant needs both before and during the program. Before the program begins, the agent can ask for participant input based on their prior experience (Foundation). During the workshop, prompting participants to ask questions about the steps or suggest alternatives, based on their attempts to master a technique they are trying in the workshop, will more actively invoke authentic participation (Self-Concept).

All of these methods foster respect for the participants' learning needs and prior knowledge from formal schooling, previous Extension participation, and personal experience. Using this participatory approach, the UF/IFAS Extension agent becomes a facilitator of participants' *self-directed learning* rather than a teacher delivering a lecture.

Program Planning for STEM Emphasis

The following checklist can be used to prepare Extension programs that address adult learners' needs (after Knowles et al. 2005):

- *Provide relevance*. Outline context to make the workshop problem- or task-oriented. In our example above, the context is a local pest problem.
- Relevance leads to internal *motivation* to learn about the problem and solutions.
- *Build on learners' own experiences*. Gauge the target audience's backgrounds on the topic and pitch the information content to suit. This may involve a separate needs assessment, studying the results of previous workshops, or an audience survey at the start of the program. In the current example, if learners are all Master Gardeners, it might be inappropriate to start with the basics of a plant needing water, nutrients, and light. For 4-H audiences, however, this level of information may be required.
- *Orient* the program around problem-solving rather than content transmission. Instead of listing steps for participants to follow, encourage participants to understand why each step is important and remain open to other potential solutions once your rationale for your plan is explained.
- Explain the *need to know*. Why are you covering this information? This could include outlining the scale of the problem; providing relevance to the participants; or setting it in a broader context of a state, regional, or national level.
- Involve the participants in the program to enhance their *self-concept* at performing the problem-solving tasks. For example, present the program as a chance to practice what they are learning by having participants perform calculations relevant to their own situation. More experienced participants may be able to draw on their expertise to co-design programming. For example, a Master Naturalist could help design a regional- or community-specific program on a particular group of plants.

An additional resource to consider consulting is the UF Department of Agricultural Education and Communication's Framework for Agricultural STEM Education, https://ufdc.ufl.edu/IR00011432/00001/pdf. This document takes disciplinary ideas from agriculture and the Next Generation Science Standards (NGSS Lead States, 2013) for K-12 students and aligns them. So if you have a workshop that emphasizes pests and you want to know what science content might be aligned with those agricultural concepts, this framework can point you to relevant content.

Program Delivery with STEM Emphasis

The following suggestions for the workshop delivery will position you as a partner in the learning process, emphasizing the connection with the collaborative process of research.

- Make your role as partner clear to the participants from the outset by setting up the structure as an interactive or hands-on workshop. Allow participants to offer their experiences and ask questions, encouraging participation and critical thinking while you serve as a "guide on the side" versus a "sage on the stage".
- Draw out participants' expertise by asking open-ended questions and giving time for them to formulate their replies. In the "Scales and Mealybugs" example, we found that clientele with different backgrounds—e.g., nursery personnel, landscapers, pesticide company representatives, and Master Gardeners—may have different perspectives that are useful to the group as a whole. The nursery personnel may have the most experience growing young plants, the landscapers have the most experience maintaining mature plants, the company representatives may know the most about industry trends with new plant protection products, and the Masters Gardeners may have undertaken more formal academic training from books and specialists.
- Give participants a moment to think, but if they do not respond after 10–15 seconds, provide possible answers in an open-ended manner to stimulate discussion, asking for their thoughts on the potential of each solution posed.
- Encourage participants to talk to and question each other directly, as this is one way they learn and solve problems in the real-world. Before critiquing a participant's response, turn it back to the rest of the group, by asking,

"What do others think? Have you had the same experience or a different one?" If you disagree with the first opinion, responses from other participants may change your mind, addressing your concern while empowering the group as knowledgeable, flexible, and creative problem-solvers.

- Provide props or live specimens for participants to identify, based on information provided earlier in the workshop. Such tasks improve knowledge acquisition and recall and allow you to gauge learning success.
- Set up participants to work in small groups to reduce their anxiety while enabling group learning.

Figure 2. Workshop participants study a satellite image of Florida together.
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Emphasizing the STEM- and Research-Basis of the Program

Developing an Ag-Extension program structured around facilitation, participation, and mutual communication, as well as content sharing, allows emphasis of the connections between agriculture and the underlying basic sciences, technology, engineering, and math. Returning to the Pest Workshop example, when discussing how to treat a pest problem with a pesticide, agents can incorporate the math required to calculate the concentration and volume of the material needed based on the labeled application rate, target pest, and plant. The agents can simultaneously incorporate science regarding how specific chemicals kill pests and address current societal concerns regarding the use of some pesticides in the environment, such as the effect of neonicotinoids on bees and other pollinators.

The agent can provide technology and engineering updates addressing the *what* and *why* of the workshop, namely the impetus for holding a workshop. For example, there may be new tools for scouting and identifying insects, which can be explained, tested, and discussed. Similarly, newly engineered interventions such as reflective screens, barriers, or repellants that physically deter insects may provide alternatives to pesticides. Again, participants can provide feedback on these technologies based on their experience. The agent can incorporate participant input (whether positive or negative) into his or her own or collaborators' research. If the agent was part of the team designing the protective structure, for example, they may learn that it is too expensive compared with alternatives. The agent may be able to re-design the structure with more cost-effective materials or pass the feedback to the designers.

Finally, programs with participant interaction better mirror the iterative and collaborative problem-solving process of STEM professionals. The Extension agent presents current knowledge and technology or design to address the problem while stimulating thinking about product developments and soliciting feedback for needed improvements. Some research programs may involve client stakeholders directly in the development phases through citizen science-style data collection or by allowing clients to test prototype designs of materials or technology.

To emphasize STEM research and design through Extension programming:

- Share the **science** about *how* specific chemicals kill pests or help plants or animals as you provide recommendations.
- Have clients compare the advantages and disadvantages of various **technologies** for plant protection.
- For **engineering**, point out specific challenges designers worked to solve, such as creating netting with holes large enough to allow beneficial insects to reach a plant but small enough to deter pests.
- When providing recommendations, have clients use **math** by calibrating the appropriate amounts of pesticide or fertilizer needed.
- Use specific examples to help clients understand the underlying iterative research and design processes to best facilitate transfer of STEM practices to other situations.
- Highlight processes researchers use to develop recommendations, including collaboration and peer review, and outline the iterative nature of research and design.

The Power of Learning STEM in Agricultural Contexts

Contextualized STEM learning does not use the repetition and practice of specific techniques or delivery of all available specific information. However, the learner has the opportunity to apply new concepts and hone decision-making practices. In the end, the participants in Extension programming will not encounter the "ideal" scenario for implementing your solution, and contextualized STEM learning will empower them to adapt to their specific situation. Perhaps the treatment suggested in the workshop will be unavailable or too expensive, or they will not have an ornamental plant problem but rather a turf or a vegetable problem. If a simple, singular solution to the ornamental pest had been provided, not all of the participants would be able to use it to their advantage.

Ultimately, contextualizing new content by explicitly referencing the need for each problem-solving step is designed to help the learner generalize and transfer their understanding to new situations. Grounding the problem in the real-world context provides meaning to the variables so that a user is more likely to be able to apply a calculation to a new situation, or at least to understand why the calculation is necessary and the consequences of miscalculation. At the very least, if participants are not comfortable doing the calculation themselves, they could consult an Extension agent or other knowledgeable person rather than guessing.

Restructuring the program to be more in line with professional Ag-STEM research and development practice helps participants to think about the purpose and importance of each step in the solution. Some clients may need additional resources, but if they have a better idea of the problem, together you can develop solutions that can in turn serve a larger client base.

Conclusion

Extension agents will benefit from clientele sharing expertise and building confidence by applying practices to real-life problems. This strategy empowers the local clientele base to be proactive problem-solvers. Clients also might contribute new ideas and data to the research and development processes of Extension faculty.

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