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Learnings and Recommendations to Advance 4-H Science Readiness

Abstract

The case study investigation reported here assessed California 4-H professionals' understanding of the essential components of effective 4-H Science programming as established by the National 4-H Science Mission Mandate. Using the 4-H Science Checklist as the basis for defining 4-H Science Readiness, academic and program staff were surveyed and interviewed to determine their understanding of what constitutes effective science programming in 4-H and their capacity to deliver science professional development and programs. Results indicated a need to build staff capacity relative to 4-H Science in California and outcomes may have implications for 4-H professionals nationally.

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Introduction

Youth Scientific Literacy: A National Issue

The National Academy of Sciences (2007) maintains that scientific literacy is critical for a robust 21st century economy. However, national and international assessments over the past several years have revealed poor science achievement among K-12 students in the United States (Fleischman, Hopstock, Pelczar, & Shelley, 2010; Gonzales et al., 2008; National Center for Education Statistics, 2011), representing a societal concern with implications at the local, state, and national levels (National Academy of Sciences, 2007). Youth who achieve below basic levels of competency are considered to be lacking in the foundational knowledge and skills necessary for scientific careers, as well as for full participation in today's knowledge-based society (National Academy of Sciences, 2007).

Achieving scientific literacy among the school-age population in the United States will require a variety of complementary strategies, including effective nonformal science programs that occur during out-of-school time (Bell, Lewenstein, Shouse, & Feder, 2009). Nonformal science education programs use learner-centered teaching strategies and reflect how science takes place in the real world (Carlson & Maxa, 1997); additionally, nonformal learning opportunities expand school curriculum offerings, stimulate youths' interest in science (Bell, Lewenstein, Shouse, & Feder, 2009), and may be more effective than classroom-based science (Sullenger, 2007).

Addressing Youth Scientific Literacy through 4-H: The 4-H Science Initiative

The 4-H Youth Development Program, a nonformal, community-based youth education organization, has the potential to help address the scientific literacy problem among school-aged youth in the United States. Nationally, 4-H youth engage in over 5.2 million science-related projects annually, including animal science, computer science, robotics, geology, astronomy, GPS/GIS, and many other content areas (USDA/NIFA, 2011). Furthermore, the learn-by-doing approach used in 4-H programs promotes the use of inquiry, experiential learning, and the authentic applications of knowledge and skills, educational strategies shown to be effective in advancing scientific literacy (e.g., Minner, Levy, & Century, 2010; National Research Council, 2011).

Developing and implementing effective science education programs to address the low levels of scientific literacy among youth in the United States are high priorities in 4-H. To help accomplish this, National 4-H Headquarters established the 4-H Science Mission Mandate (referred to as "4-H Science") that articulates national priorities and helps guide science programming efforts at the state level (Schmiesing, 2008). These science program priorities are outlined in the 4-H Science Checklist (Figure 1) (National 4-H SET Leadership Team, 2010), which summarizes essential components of "4-H Science Readiness," referring to the science content knowledge and process skills necessary to advance scientific literacy in a positive youth development context. The 4-H Science Checklist can also be used as a tool for state 4-H programs to evaluate their existing science programming, as well as plan future efforts.

Figure 1.

4-H Science Checklist

	Are you providing science, engineering and technology programs based on National Science Education Standards? *Science education standards are criteria to judge quality: the quality of what young people know and are able to do; the quality of the science programs that provide the opportunity for children and youth to learn science; the quality of science teaching; the quality of the system that supports science leaders and programs; and the quality of assessment practices and policies.* *http://www.nap.edu/readingroom/books/nses/*
	Are you providing children and youth opportunities to improve their Science Abilities? *Predict, Hypothesize, Evaluate, State a Problem, Research Problem, Test, Problem Solve Design Solutions, Measure, Collect Data,*

	Draw/Design, Build/Construct, Use Tools, Observe, Communicate, Organize, Infer, Question, Plan Investigation, Summarize/Relate, Invent/Implement Solutions, Interpret/Analyze/Reason, Categorize/Order/Classify, Model/Graph/Use Numbers, Troubleshoot, Redesign, Optimize, Collaborate, Compare
	Are you providing opportunities for youth to experience and improve in the Essential Elements of Positive Youth Development? • *Do youth get a chance at* ***mastery*** *– addressing and overcoming life challenges in your programs?* • *Do youth cultivate* ***independence*** *and have an opportunity to see oneself as an active participant in the future?* • *Do youth develop a sense of* ***belonging*** *within a positive group? Do youth learn to share a spirit of* ***generosity*** *toward others?*
	Are learning experiences led by trained, caring adult staff and volunteers acting as mentors, coaches, facilitators and co-learners who operate from a perspective that youth are partners and resources in their own development?
	Are activities led with an experiential approach to learning?
	Are activities using inquiry to foster the natural creativity and curiosity of youth?
	Does your program consider the frequency and duration necessary for youth to accomplish outcomes?
(National 4-H SET Leadership Team, 2010)	

Achieving Youth Scientific Literacy through 4-H: The Need for Effective Professional Development

Effective science programming needs effective science educators. In 4-H, adult volunteers serve most commonly in the role of nonformal educators and must have access to and participate in professional development opportunities that target improved knowledge and skills (Hoover & Connor, 2001) and are systematic and intentional in their design (Smith & Schmitt-McQuitty, 2013). The responsibility of providing professional development in science for adult volunteers lies with 4-H academic and program staff. To accomplish this effectively, however, 4-H academic and program staff require the knowledge and skills to teach science content, pedagogy, educational standards, positive youth development, and science process skills, fundamental components of 4-H Science Readiness.

Methods

The qualitative investigation with Human Subject approval by the University of California Internal Review Board reported here used a case study approach bounded by a program (4-H Youth Development Program) and the people involved (4-H Advisors and Program Representatives) (Hatch, 2002). Participants were county-based 4-H professionals who direct 4-H Science programming at the local level. Specifically, 4-H Advisors are responsible for the academic responsibilities associated with the 4-H Youth Development Program; Program Representatives manage the day-to-day operations of the 4-H Program.

The focus of the work was to investigate the understanding of 4-H Science and what constitutes 4-H Science Ready programming among academic and program staff in California 4-H. Specifically, investigators sought to gain an understanding of 4-H staff members' knowledge relative to the programmatic criteria, educational theory, and youth development framework associated with 4-H Science. Outcomes are intended to help inform the California 4-H Youth Development program with potential relevance to 4-H programs nationally in order to better prepare Extension professionals to incorporate 4-H Science into their county programs.

Methodology

Surveys were developed to assess 4-H staff members' understanding of the elements that comprise the 4-H Science Mission Mandate (National 4-H Headquarters, 2011) and to capture information about the types of science programming occurring in county programs. Interviews were conducted to expand upon survey outcomes and draw further inferences about local 4-H science programming.

Data Sources

Surveys

The 4-H Science Checklist (Figure 1) was used to develop a short, free-response survey. The survey focused on collecting data related to academic and program staff members' understanding of the foundational elements of 4-H Science programming.

The survey included the following questions:

1. Describe a 4-H Science Ready project or activity taking place in your county.
2. In your opinion, what components make that project or activity 4-H Science Ready?
3. How, if at all, do 4-H Science projects and activities look different from non-4-H Science activities?

Web-based surveys were disseminated to all 4-H Youth Development Program faculty and staff in California (N=78). Staff members were provided 3 weeks to complete the survey; three follow-up email reminders were sent at 2-week intervals. Survey responses included respondents' position within 4-H (faculty or staff), but all other data were anonymous. Twenty-six surveys (13 faculty; 13 staff) were completed, representing a 33% response rate.

Interviews

After survey data collection was completed, follow-up telephone interviews were conducted with a stratified random subset of Youth Development Advisors and Program Representatives. In order to ensure geographic representation, the Youth Development Advisors and Program Representatives selected were from counties in the northern, central, and southern regions of the state. Youth Development Advisors and Program Representatives from the same county were not eligible for selection.

In-depth individual interviews were conducted via telephone by the author with six 4-H Youth Development Advisors and five Program Representatives. All interviews were recorded and transcribed for analysis. Interview questions included the following.

1. What materials/resources do you use for your 4-H Science programs and activities?
2. How do you know these materials/resources are 4-H Science Ready?
3. Which National Science Education Standards are identified in the materials/resources that you use?
4. Describe how these materials/resources make specific 4-H Science Abilities evident through activities.
5. Explain how these materials/resources create opportunities for youth to experience and improve the Essential Elements of Positive Youth Development: Mastery, Independence, Belonging and Generosity toward others.
6. Provide an example of how these materials/resources provide learning experiences that are led by trained, caring adult staff and volunteers who operate from a perspective that youth are partners and resources in their own development.
7. Describe how the science learning experiences in your 4-H Science programs and activities use experiential learning strategies and create opportunities for: sharing/processing/generalizing and application.
8. Give an example of how these science learning experiences are designed using inquiry methods, such as learner-centered exploration and open-ended questioning.
9. Explain how these science learning experiences are designed for extended frequency and duration that serve to scaffold learning.

Data Analysis and Results

Data Analysis

In order to interpret the data fully, survey and interview responses were coded and grouped into typologies created from predetermined categories found on the 4-H Science Checklist. The typologies included the following.

1. *Content and Science Processes Typology*: This was created to capture data relating to participants' understanding of the National Science Education Standards (National Research Council, 1996) and the 30 4-H Science Abilities (Worker, 2012; Table 1).

2. *Effective Science Pedagogy Typology*: This was developed to include data from survey and interview questions that centered on attributes associated with effective science instruction, including experiential learning, inquiry, and extended learning opportunities (e.g., Minner, Levy, & Century, 2010; National Research Council, 2011).

3. *Youth Development Typology*: This was developed to capture responses by survey and interview participants related to their knowledge and use of Youth/Adult Partnerships (Zeldin, Camino, Calvert, & Ivey, 2002) and the Essential Elements of Youth Development (Martz, Mincemoyer, & McNeely, 2009).

Table 1.
4-H Science Abilities

Build/Construct	Make by putting materials together.
Categorize/Order/Classify	Put objects or events in groups or classes.
Collaborate	Work together; applies both to the work of individuals as well as larger groups.
Collect Data	Record information in an organized fashion about objects and events that illustrate a specific situation.
Communicate/Demonstrate	Methods for involving various media that transfer information from one person to another.
Compare/Contrast	Examine and evaluate similarities and differences. All measurements are forms of comparing.
Design Solutions	Written plan or design that identifies a problem to be solved, its criteria, and its constraints.
Develop Solutions	Systematic strategy used to develop many possible solutions to solve a problem or satisfy human needs and wants.
Draw/Design	Plan in systematic graphic form; process of

	originating and developing a plan for a product, structure, system or component.
Evaluate	Technique of examining and judging data presented.
Hypothesize	State of tentative generalization, which is subject to immediate or eventual testing by one or more experiments; to explain a relatively large number of events.
Invent/Implement Solutions	Practical application to fulfill a desired purpose.
Infer	Explain an observation in terms of one's previous experience. Leads to predictive explanations.
Interpret/Analyze/Reason	Determine the nature and relationship of the parts of the whole. Find a pattern inherent in a collection of data. This process leads to stating a generalization or drawing conclusions. In an experiment, it is the process by which one establishes the relationship between controlled factors and the outcome.
Measure	Procedure by which one uses an instrument to estimate a quantitative value associated with some characteristic of an object or event.
Model/Graph/Use Numbers	Devise a scheme or structure that will describe specific real objects or events.
Observe	Most basic process of science, in which learners use their senses to obtain information about themselves or the world around them.
Optimize	Make the best or most of a condition.
Organize/Order/Classify	Put into working order; get together and arrange.
Plan Investigations	Use a body of techniques, often referred to as the Scientific Method, for considering phenomena and acquiring knowledge, including the elements of hypothesis development, prediction, and the effects and limits of observation and based on gathering observable, empirical, measurable evidence, subject to the principles of reasoning .
Predict	Projecting future observations on the basis of previously known information.

Problem Solve	Part of the thinking process considered the most complex of all intellectual functions that includes problem finding and problem shaping.
Question	Raise an uncertainty, doubt, or unsettled issue that may be based on the perception of a discrepancy between what is observed and what is known by the questioner.
Redesign	Plan, draw or sketch again.
Research a Problem	Active, diligent, and systematic process of inquiry aimed at discovering, interpreting and revising facts. Is usually associated with the output of science and the scientific method.
State a Problem	First step in the engineering process focused on assessing/creating the need in order to define the problem to be solved.
Summarize	Make a brief statement giving the main points of substance of a matter.
Test	Verify or falsify an expectation with an observation, often as part of an experiment within the scientific method.
Troubleshoot	Systematic search for the source of a problem so that it can be solved.
Use Tools	Manipulate objects, instruments and materials as a means of furthering a learner's understanding, appreciation and application of scientific knowledge.
(Worker, S.M. 2012)	

Specifically, data were assessed looking initially for responses that applied to individual typologies and subsequently identified patterns, relationships, or themes within typologies (Hatch, 2002). This approach is an appropriate method for analysis when there are initial groupings of data and the research is designed to capture the understanding of a group of individuals around a specific topic (Hatch, 2002).

Results

Content and Science Processes Typology

National Science Education Standards

Survey results revealed that few Advisors (two of 13) or Program Representatives (one of 13) made specific reference to the National Science Education Standards (NSES) as a component of 4-H Science Readiness. When asked during interviews which of the NSES were identified in the materials they are using, only three of six Advisors and none of the Program Representatives could name specific standards addressed in the materials they used in 4-H Science programming. Most responses by participants reflected either a lack of knowledge or awareness of the NSES: "I don't know"; "I'm not aware"; or, "I'd have to look."

4-H Science Abilities

Survey results indicated that two of 13 Advisors and three of 13 Program Representatives mentioned 4-H Science Abilities as components of 4-H Science Readiness. Rather than identifying specific 4-H Science Abilities (e.g., observe, compare, predict, and measure), staff members referred to pedagogical strategies such as experiential learning, inquiry, open-ended questioning, and learner-centered instruction.

When asked during interviews to describe how curriculum materials and resources make 4-H Science Abilities evident, two of the six Advisors could identify specific abilities (e.g., problem solving, observation, testing, and measuring). None of the Program Representatives were able to provide any examples.

Effective Science Pedagogy Typology

Experiential Learning

Survey results revealed that six of 13 4-H Youth Development Advisors and five of 13 Program Representatives were able to identify experiential learning as a component of effective science teaching. This was evidenced by survey responses such as: "...using hands-on, experiential education as a teaching model" in 4-H Science and 4-H science programming has "components of experiential learning [and a] focus on practical [applications]."

When interviewed, one of the six Advisors and two of the five Program Representatives demonstrated an understanding of experiential learning. When asked to share evidence that experiential learning was taking place in their science programs, most interview respondents could not articulate what experiential learning looked like in practice. This outcome was demonstrated through comments such as "I honestly can't think of what's going on in the club program. I mean, we train around [experiential learning] but whether it's actually getting implemented, I don't know."

Inquiry

Survey outcomes indicated that eight of 13 4-H Youth Development Advisors and 10 of 13 Program Representatives were able to identify inquiry as a strategy to teach science. Specific survey responses to this end included: "The inquiry approach is embedded in each curriculum" and "[volunteers] are informed about inquiry-based, learner-based instruction." However, when asked during interviews to provide an example of how learning experiences in their 4-H Science programming efforts were designed using inquiry methods, only two of the six Advisors were confident that inquiry was being used in science learning experiences offered to youth in their county programs. For example, one Advisor responded: "By assessing what learners know in advance of the lesson, the use of open ended questions like 'what happened or what did you experience' helps with the application of concepts." Of the remaining Program Representatives and Advisors, none provided examples of learning experiences in their county programs that used inquiry methods, and most exhibited no understanding of inquiry-based learning. A few respondents used appropriate terminology, but out of context.

Opportunities for Extended and Scaffolded Learning

When surveyed, no 4-H Youth Development Advisors or Program Representatives identified opportunities for extended and scaffolded learning as part of 4-H Science Readiness. However, all Advisors interviewed were able to explain how extended learning experiences serve to scaffold learning. For example, one Advisor stated that the "Power of the Wind [curriculum] is definitely about scaffolding information, knowledge and building upon experiences to gain a higher level of knowledge." Three of the six Advisors recognized extended learning opportunities as a component of 4-H Science. None of the Program Representatives interviewed exhibited an understanding of extended and scaffolded learning.

Positive Youth Development Typology

Essential Elements of Positive Youth Development:

When surveyed, only one of 13 4-H Youth Development Advisors and two of 13 Program Representatives identified the Essential Elements as part of 4-H Science Readiness. When interviewed, four of six Advisors demonstrated an understanding of the Essential Elements and were also able to identify their presence in the materials being used for 4-H Science. For example, "using teen teachers has allows them to develop mastery, generosity and belonging by putting them in a leadership role." One of the five Program Representatives interviewed was aware of the inclusion of the Essential Elements in materials used for 4-H Science; two other Program Representatives were aware that the Essential Elements were a part of 4-H Science, but could not say for certain if they were present in the materials being used.

Youth-Adult Partnerships

Survey results revealed that two of 13 Advisors were able to identify youth-adult partnerships as part of 4-H Science Readiness, while one of the Program Representatives was able to do so. When interviewed, three of the six Advisors and one of the five Program Representatives provided examples where youth-adult partnerships were evident or could take place. Sample interview responses included: "So, Rocketry Camp; junior/teen leaders help put that on"; "I can say that with the GPS/GIS project..., typically the kids are helping identify sites... [and] they're basically developing material that's going to be extended..."

Discussion

Results from the investigation reported here demonstrated a general lack of understanding among 4-H staff in California across all core components of 4-H Science Readiness. For example, both Advisors and Program Representatives exhibited limited understanding of experiential learning and how to incorporate it in their 4-H Science programming. Relative to the use of inquiry, respondents knew that it was a component of 4-H Science Readiness; however, few participants exhibited an understanding of the elements of inquiry-based learning and could not describe its use in 4-H Science programming in their counties. 4-H Youth Development Advisors who participated in the investigation had a much stronger understanding of the importance of extended learning opportunities and how they could scaffold learning among youth participants than did Program Representatives. Understanding the components of positive youth development and youth-adult partnerships in 4-H Science was limited for both Advisors and Program Representatives. This was an unexpected result since these are concepts that are fundamental to the 4-H Youth Development Program regardless of program or project area.

Based on survey and interview results, there is a need for effective professional development in science for California 4-H staff. To accomplish this, the state program will focus professional development in science on the knowledge, skills, and attitudes among participating educators (Garet, Porter, Desimone, Birman, & Yoon, 2001; Guskey & Sparks, 2002). Furthermore, professional development models will be grounded in research-based teaching methods that include strategies on how people learn (Garet et al., 2001) and model effective practice (Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2003). Furthermore, California 4-H will use educator professional development models in science that include the following features (e.g., Garet et al., 2001; Penuel, Fishman, Yamaguchi, & Gallagher, 2007).

- Extended Duration. Professional development that occurs over an extended period of time to help promote educators' understanding through additional opportunities for reflection and discussion.
- Active Learning. Active learning helps educators grasp new ideas by challenging their prior understanding.
- Effective Pedagogy. Emphasizing effective pedagogical strategies in science helps educators apply these practices in authentic settings.
- Content Knowledge. Advancing educators' competencies relative to science content promotes the use of effective science pedagogy.
- Authentic Context. Science professional development opportunities that occur in authentic settings promote the application of new knowledge and skills by educators.
- Use of Data. Authentic data from target audiences helps advance educators' practice.
- Connections to Broader Organizational and Systemic Efforts. Professional development opportunities that link to broader goals help address educators' needs and promote communication.

Examples of effective professional development models that will be explored include incremental workshops (e.g., Smith & Enfield, 2002), lesson study (e.g., Smith, 2013), mentoring (e.g., Byington, 2010), and communities of practice (e.g., Smith & Schmitt-McQuitty, 2013). Based on the outcomes from the investigation, it will also be essential that the content of these professional development opportunities in science emphasize, but not be limited to, the following areas: recognizing and using inquiry methods; experiential learning; effective questioning strategies in science; reflective practice; Next Generation Science Standards (NGSS, 2013); 4-H Science Abilities; youth-adult partnerships; positive youth development; and scaffolding science understanding through extended learning opportunities.

Conclusion

Extension programs are intended to support national initiatives at the local level. To accomplish this, Extension professionals, in their role as extension educators, implement research-based programs with their constituents (Mincemoyer, Perkins, & Lillehoj, 2004). For Extension programs to be effective, however, the development of staff competencies is imperative (Stone & Coppernoll, 2004). The investigation reported here resulted in California 4-H making specific recommendations regarding effective professional development designed to improve the capacity of county-based staff as it relates to 4-H Science. Outcomes from the investigation highlight the value in confirming how well a mandate is understood and being implemented and could act as a cautionary example for other state 4-H programs. Additionally, the recommendations for improving 4-H staff competencies in science in California 4-H may be applicable to other state programs and could be investigated further.

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