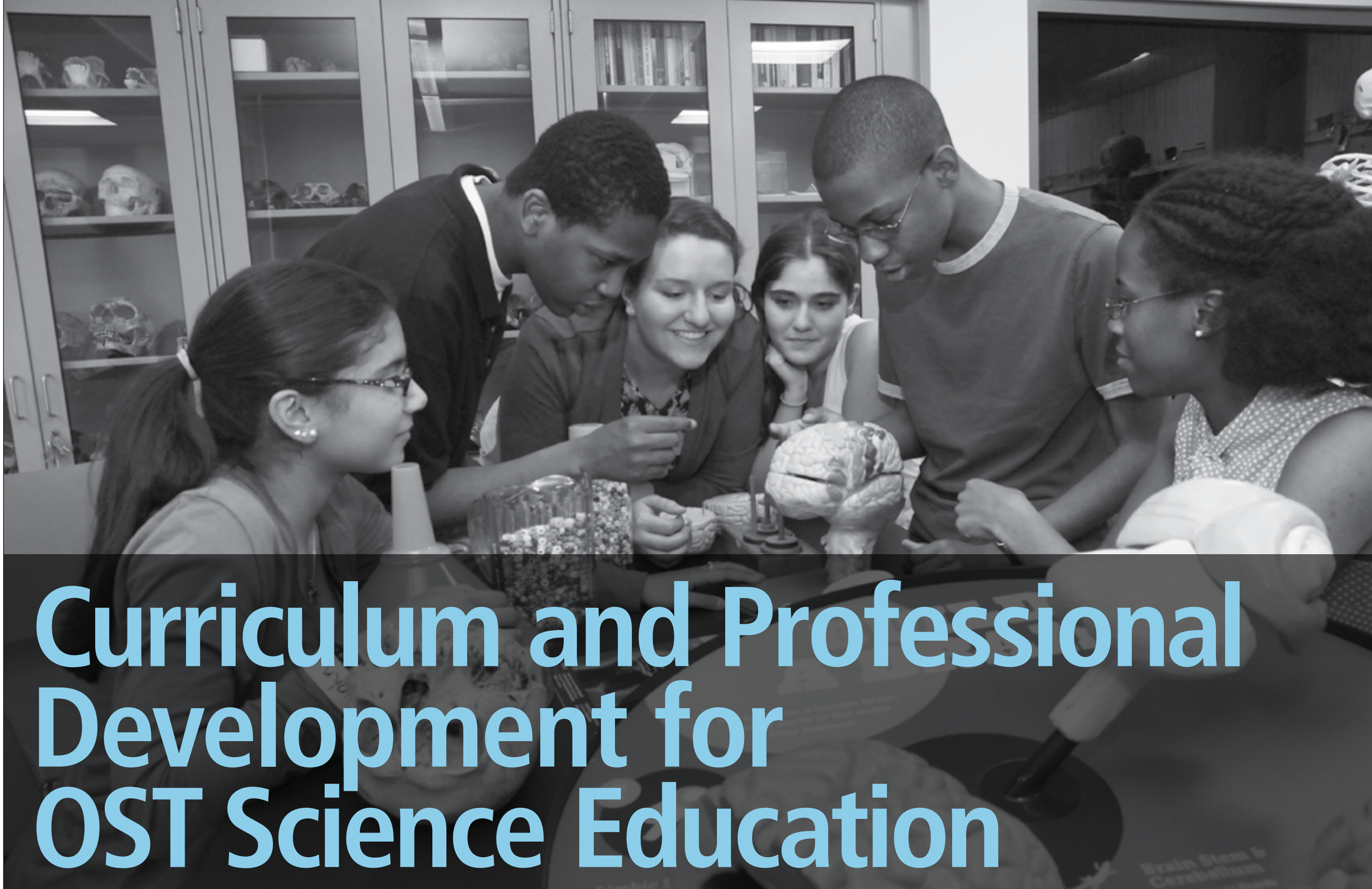

Curriculum and Professional Development for OST Science Education

Lessons Learned from California 4-H

by Steven M. Worker and Martin H. Smith

A wide variety of out-of-school time (OST) programs across the U.S. offer science education opportunities that cover many scientific disciplines and use diverse pedagogical practices (National Research Council [NRC], 2009). However, to improve youth's scientific literacy, OST educators need to "have the disposition and repertoire of practices and tools at their disposal to help learners expand on their everyday knowledge and skill to learn science" (NRC, 2009, p. 309). Thus, OST educators need both essential pedagogical skills and high-quality curriculum materials.

Grounded in literature on best practices in science education, this article describes a systematic and intentional approach to developing OST science curricula and professional development models. Examples from the California 4-H Science, Engineering, and Technology Initiative demonstrate promising practices in action.

How the 4-H Youth Development Program Strengthens Scientific Literacy

4-H is a national community-based youth development organization administered through the Cooperative Extension System, an educational partnership among the U.S. Department of Agriculture (USDA), state land grant universities, and county governments (Kellogg Commission on the Future of State and Land Grant Institutions, 1999). Grounded in Cooperative Extension's

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mission and history related to agriculture, science, mechanical arts, and education, county-based 4-H programs provide hands-on, experiential education opportunities to youth in all 50 states and the District of Columbia (USDA, 2003).

In response to research that indicates low levels of scientific literacy among K–12 students in the U.S. (National Center for Education Statistics, 2011), the national 4-H program strengthened its commitment to science education by introducing the 4-H Science Mission Mandate (Kress, McClanahan, & Zaniewski, 2008). With the goal of improving scientific literacy among youth, 4-H Science provides coordinated plans of action to state 4-H programs. Specific areas of focus include curriculum development; improved professional development for staff and volunteers; enhanced development of local, state, and national partnerships; systematic program evaluation; and targeted funding development (Schmiesing, 2008).

Inquiry, a constructivist process, engages youth in learning and applying science content in ways that have been shown to be effective in fostering scientific literacy (Beerer & Bodzin, 2004). Activities are sequenced to "spiral" major concepts, revisiting and reexamining them over several lessons so that learners build knowledge in multiple small steps (Bruner, 1996).

In support of 4-H Science, the California 4-H Youth Development Program established the 4-H Science, Engineering, and Technology (SET) Initiative (University of California Agriculture and Natural Resources [UC ANR], 2008). Two key goals of the initiative are to:

- Develop curricula that meet the environmental and social needs of Californians, as outlined in the UC ANR *Strategic Vision 2025* (Regents of the University of California, 2009)
- Build staff capacity through effective professional development for informal educators

Developing Curricula

High-quality curriculum materials are critical for effective science education. According to Tyler (1949) and Wiggins and McTighe (2005), curricula should:

- Be based on identified needs
- Include targeted learning objectives
- Organize content to build learning over time
- Be structured around effective approaches to teaching and learning
- Provide opportunities to evaluate outcomes
- Include explicit, real-world applications
- Provide opportunities for focused reflection

A curriculum should be more than a list of facts to be memorized; rather, the content should present major scientific concepts in a systematic fashion (Bybee, 2002). Additionally, science curriculum content should emphasize the development of scientific abilities, such as asking questions and defining problems; planning and implementing investigations; and collecting, analyzing, and interpreting data (Bybee, 2002; Bybee, 2011; NRC, 2012). Curriculum content should be developmentally appropriate (Seimears, Graves, Schroyer, & Staver, 2012) and build on learners' prior knowledge (Strangman, Hall, & Meyer, 2004). A curriculum's learning experiences must connect to target learning objectives (Wiggins & McTighe, 2005).

The prevalent model of science pedagogy has been the *transmission* model, which uses lectures, presentations, and assigned readings to convey science knowledge. However, this model has no theoretical justification and is not effective (Seimears et al., 2012). In contrast, the *constructivist* model involves learner-centered experiences and inquiry, in which individuals make sense of new information using their prior knowledge (Mestre, 2005).

Evaluation of a curriculum helps to confirm that learning has occurred (Wiggins & McTighe, 2005). Systematic collection and analysis of data help to ensure that a curriculum is more than just content to memorize or a disconnected series of learning activities. To facilitate effective evaluation, program developers should decide in the early stages of curriculum development how to define and measure acceptable evidence of understanding (Wiggins & McTighe, 2005).

Curriculum developers in the California 4-H SET Initiative have focused on designing and evaluating needs-based curricula that use sequenced activities to guide inquiry into science content, thereby building scientific skills. Inquiry, a constructivist process, engages youth in learning and applying science content in ways that have been shown to be effective in fostering scientific literacy (Beerer & Bodzin, 2004). Activities are sequenced to "spiral" major concepts, revisiting and reexamining them over several lessons so that learners build knowledge in multiple small steps (Bruner, 1996). Experiential education promotes a deep understanding of subject matter; it includes application of new knowledge and skills in authentic settings (Eyler, 2009). Applying new knowledge to additional experiences is congruent with service learning components in 4-H curricula. Practical application of new skills nurtures youth participation in community and social settings (Lave & Wenger, 1991).

California 4-H SET curricula are intentionally structured to promote positive youth development, which involves programmatic strategies that help youth transition successfully to adulthood (National Research Council & Institute of Medicine, 2002). Positive youth development helps youth build skills and develop healthy relationships, both of which are necessary for youth to achieve desirable life goals (Lerner et al., 2011). It also entails giving youth opportunities to work as partners in their own development, support their own growth, and achieve their potential (Small & Memmo, 2004).

To develop new curricula for California SET, academic and program staff used Wiggins and McTighe's (2005) *Understanding by Design*, a framework with three steps:

- **Identify desired outcomes.** Learning goals might include deepening knowledge, enhancing skills, improving attitudes, changing behavior, and promoting positive youth development.
- **Determine acceptable evidence of learning.** How will educators know if learners have achieved the desired outcomes? Evidence of learning may include success indicators, such as performance tasks, discrete skills, or generalizations to real-world examples, as well as other kinds of embedded assessment relevant to OST.
- **Plan and design learning experiences.** The *Understanding by Design* process enables curriculum developers to connect activities to desired outcomes and to sequence activities so that learning is systematic over time.

Using these principles to develop science curricula is a core component of the California 4-H SET Initiative. Three examples of curricula developed using Wiggins and McTighe's framework are outlined below.

Bio-Security in 4-H Animal Science

Cooperative Extension staff, in collaboration with veterinarians, developed and tested the *Bio-Security in 4-H Animal Science* curriculum (Smith et al., 2011) to help youth learn about managing endemic and invasive pests and diseases (Regents of the University of California, 2009). The curriculum covers disease transmission, disease risks, and risk mitigation strategies. Activities allow youth to apply new knowledge and skills directly to the raising of their 4-H project animals.

Evaluation of the curriculum focused on perceived changes in youths' knowledge of curriculum content. Outcome data were collected using retrospective surveys (Pratt, McGuigan, & Katzev, 2000) of participating youth. This type of survey design reduces the problem of response-shift bias that often occurs when using pre- and post-participation surveys. Response-shift bias occurs when participants have such limited knowledge to apply to pre-participation survey questions that their responses overestimate their abilities (Raidl et al., 2004). Analysis of outcome data on *Bio-Security in 4-H Animal Science* revealed significant ($p < .05$) gains in youth's understanding of bio-security science.

Junk Drawer Robotics

Robotics has been shown to be an effective cross-disciplinary content area for SET education (Barker, Nugent, Grandgenett, & Adamchuk, 2012) with potential connections to an array of agricultural and natural resource issues (Regents of the University of California, 2009). Employing an iterative development process, California 4-H academics developed the *Junk Drawer Robotics* curriculum to be used with middle school youth (Mahacek, Worker, & Mahacek, 2011). The content of each module is intentionally organized to spiral education in three phases:

- To Learn (Science) activities emphasize exploration and form the foundation on which youth build conceptual understanding.
- To Do (Engineering) activities build on the conceptual knowledge gained in the exploration phase.
- To Make (Technology) activities put youth to work in groups to build and test a solution to a design problem while solidifying their understanding of concepts.

Youth outcomes were assessed using a pre-post instrument with Likert scale questions and open-ended content questions. Participating youth demonstrated increased interest in science and engineering and deeper conceptual understanding of science, engineering, and robotics (Mahacek & Worker, 2011).

There's No New Water!

In response to a call for education on water issues ("Present U.S. Water Usage," 2008) and in connection with an organizational initiative to improve water quality, quantity, and security (Regents of the University of California, 2009), Cooperative Extension staff and a team of undergraduate students developed and tested *There's No New Water!* (Smith et al., 2010). The curriculum, which targets youth of middle and high school age, is framed around an experiential education cycle. It promotes youth inquiry into topic areas including the natural water cycle, human interventions that affect water quality and quantity, and the mapping of watersheds. The curriculum also emphasizes service learning projects that address local water issues.

Evaluation of the curriculum used a retrospective Likert-style survey in which youth participants reported on changes in their content knowledge. Youth also completed a post-participation survey on life skills development. Outcomes showed statistically significant ($p < .01$) increases in content knowledge around topics such as water distribution, water conservation, water quality, source pollutants, and watersheds. Advances in life skills were seen in the areas of citizenship, leadership, responsibility, and cooperation and communication (Smith, Heck, & Worker, 2012).

Developing Educators

Effective professional development of science educators is one of many factors that contribute to improving scientific literacy among youth (Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2003). Ensuring that practitioners are prepared to teach science effectively requires professional development that focuses both on science content and on pedagogy (Garet, Porter, Desimone, Birman, & Yoon, 2001; Loucks-Horsley et al., 2003). Community-based OST programs can help address the need to improve scientific literacy among K–12 youth (Kress et al., 2008; NRC, 2009). However, many OST educators have not participated in science education professional development (Chi, Freeman, & Lee, 2008).

The 4-H Youth Development Program relies heavily on volunteers—adults and teens—who facilitate educational activities with youth (Stedman & Rudd, 2006). Discrete in-person workshops represent the most common approach to professional development for these volunteers (Kaslon, Lodl, & Greve, 2005). However, many researchers consider such workshops to be ineffective because they do not model effective science pedagogy and do not produce significant change in educators' practice. In contrast, research supports professional development that is offered over an extended period of time; uses active, constructivist strategies; and emphasizes both subject matter and pedagogical knowledge (Garet et al., 2001; Guskey & Yoon, 2009; Loucks-Horsley et al., 2003).

Development, evaluation, and use of effective professional development strategies are key components of the California 4-H SET Initiative. Examples grounded in literature on best practices in professional development of science educators are outlined below.

The "Step-Up" Incremental Training Model for Teens

The "Step-Up" Incremental Training Model targets 4-H teen volunteers who implement science curricula with 4-H youth (Smith & Enfield, 2002). A sequence of three workshops engages teen volunteers in hands-on, inquiry-based science activities and effective teaching techniques. The volunteers alternate between workshops and actual implementation of the curriculum. Allowing time for implementation between workshops provides opportunities for individuals and groups to reflect on their practice over several weeks.

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Analysis of pre- and post-participation survey and observational data provided statistically significant ($p < .01$) evidence that the Step-Up model was effective in improving teens' understanding of and ability to use effective questioning strategies and inquiry methods (Smith, Enfield, Meehan, & Klingborg, 2004). Furthermore, the teens were successful in the role of cross-age science teachers. Data on critical thinking skills were collected from children using an objective measure; results revealed statistically significant ($p < .05$) improvements (Smith et al., 2004).

Lesson Study

Lesson study is constructivist professional development that engages educators in developing an inquiry stance toward their practice through active reflection; it is situated in authentic contexts and occurs over time (Lewis, 2002; Wiburg & Brown, 2007). In lesson study, teams of educators formulate collective goals, collaborate to improve lessons, and explore issues of teaching and learning (Lewis, 2002; Wiburg & Brown, 2007). Lesson study has been shown to have positive effects on classroom educators' knowledge, skills, and confidence (Rock & Wilson, 2005; Wiburg & Brown, 2007) and their abilities to design and teach science lessons (Marble, 2006).

A recent study—the first on lesson study for OST practitioners—investigated the influence of lesson study on 4-H volunteers' understanding and use of inquiry methods and on their veterinary science content knowledge (Smith, 2013). Retrospective survey data showed a significant effect

($p < .01$) of time on both constructs. Focus group interviews elaborated on participants' understanding and use of inquiry processes, including questioning strategies, learner-centered explorations, and application of knowledge.

Tools of the Trade II

California and Nevada 4-H prepared the professional development curriculum *Tools of the Trade II: Inspiring Young Minds to Be Science, Engineering, and Technology Ready for Life!* (Junge, Manglallan, Reilly, & Killian, 2010). The curriculum includes 21 hours of activities to help adult educators improve their ability to facilitate OST science education. Modeling effective practice by using a hands-on approach, the curriculum is designed to increase staff knowledge, skills, and confidence in delivering high-quality science experiences.

To assess the effectiveness of *Tools of the Trade II*, a multi-site evaluation using a retrospective survey was employed with staff from a diverse cross-section of afterschool providers throughout California. Outcomes demonstrated a significant improvement ($p < .01$) in participants' understanding of science processes and of how to create science-rich environments. Participants reported that the most important strategies they learned were inquiry, experiential education, and effective questioning (Junge & Manglallan, 2011).

Promising Practices in Out-of-School Time Science Education

In addition to the agriculture programs for which it is known, 4-H in the 21st century offers programming in many other content areas, including astronomy, aviation, computer science, ecology, and plant science; it has expanded beyond the traditional club setting to include more venues, such as afterschool programs and summer camps (Enfield, 2001). To address youth scientific literacy across these subject matter areas and settings, the California 4-H SET Initiative has systematically and intentionally developed, implemented, and evaluated curricula and professional development models for adult and teen volunteers.

Effective curricula involve youth in constructing knowledge and making meaning through learner-centered activities and authentic application of new knowledge and skills. These strategies have a theoretical foundation (Kolb, 1984; Vygotsky, 1978), have been shown to be effective in teaching and learning science, and are congruent with national standards. As our examples show, curricula developed by the California 4-H SET Initiative focus on the use of effective pedagogy, including inquiry and experiential education. Subject matter is determined by organizational priorities, which were developed through a needs assessment involving internal and external stakeholders (see Regents of the University of California, 2009).

Effective professional development for science educators also uses constructivist strategies. Active, learner-centered activities position educators as learners in relation to their own practice, and professional development occurs over an extended period of time (Smith & Schmitt-McQuitty, 2013). These features increase educators' investment in professional development and help them acquire new knowledge and skills.

Future Opportunities for Research and Practice

OST science education has been recognized as an important contributor to youth scientific literacy (Afterschool Alliance, 2011; NRC, 2009). The national 4-H Science Mission Mandate and the California 4-H SET Initiative are examples of organizational efforts to address youth scientific literacy through OST programming.

Curriculum development and professional development are critical priorities in 4-H, but applied research in other areas of OST science is also essential. Research in the California 4-H SET Initiative is focusing on the effects of frequency and duration of science programming, the effects of positive youth development on science learning outcomes, and service learning as a way for youth to apply their scientific knowledge and skills while contributing to the community in meaningful ways.

The California 4-H SET Initiative is advancing promising practices in OST science education through systematic research, development, and evaluation. These efforts not only are applicable to 4-H programming nationally but also can inform the work of other organizations looking to design and implement effective OST science programs for youth.

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