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Abstract

The 4-H Science Initiative has renewed efforts to strengthen 4-H programmatic and evaluation efforts in science and engineering education. A fundamental component of this initiative is to provide opportunities to youth to aid in their development of science process skills; however, emerging research stresses the importance of engaging youth in authentic practices of science and engineering. Refocusing 4-H efforts on a sociocultural framework of science education that emphasizes a participation-oriented framework towards learning scientific and engineering practices ensures 4-H programs are affording youth high-quality learning experiences.

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4-H Science Initiative and Science Process Skills

The National 4-H Science, Engineering, and Technology (SET) Initiative was announced in 2007 (4-H National Headquarters, 2007), renamed to 4-H Science, as the newest effort to strengthen 4-H science education (Worker, 2012). The National 4-H Science Leadership Team developed a set of best practices titled "4-H SET Checklist" to help educators ensure their programs exemplified high-quality science education (4-H SET Checklist, n.d.). The checklist asks, "Are you providing youth opportunities to improve their SET Abilities?" 4-H efforts have emphasized the development of science process skills (e.g., Clarke, 2010; Mielke, LaFleur, & Sanzone, 2010), which refer to measurable behaviors and transferable abilities reflective of processes involved with scientific reasoning (Padilla, 1990). In 1963, the report *Science in 4-H Study* advised 4-H programs to engage youth in science process skills (National 4-H Club Foundation, 1963). A 2007 report, *Science, Engineering, and Technology (SET) Programming in the Context of 4-H Youth Development*, reiterated this recommendation by identifying 30 4-H Science, Engineering, and Technology Abilities (Horton, Gogolski, & Warkentien, 2007).

In the broader realm of science education, a myriad of lists exist defining pure process skills. Notable lists include Revised Bloom's Taxonomy cognitive process dimension, which included remembering, understanding, applying, analyzing, evaluating, and creating (Anderson & Krathwohl, 2001); 1990 California State Science Framework (California State Department of Education, 1990) adopted in the guide *Science Guidelines for Non-Formal Education* (Carlson & Maxa, 1997), which defined observing, communicating, comparing, ordering, categorizing, relating, inferring, and applying; and the Exploratorium Institute for Inquiry's list comprised of observing, questioning, hypothesizing, predicting, planning, interpreting, and communicating (Rankin et al., 2006).

These lists have value in extending the scope of science education beyond content memorization. However, in educational application, they often suffer from a shared weakness by reducing science processes to simple procedures that neglect deepening understanding of scientific reasoning and the breadth of scientific practice (National Research Council [NRC], 2012). Research recognizes that science process skills cannot be taught or learned as independent, abstract processes apart from the both the content and the community in which they are inexplicably tied (Lehrer & Schauble, 2007). Learning science process skills in isolation is akin to memorizing content from a textbook: such learning becomes ritualized and meaningless, reducing the complex nature of scientific thinking to a set of simple procedures (Lehrer & Schauble, 2007).

Scientific and Engineering Practices: Learning Embedded Within Sociocultural Communities

Research in education is beginning to recognize the importance of sociocultural influences on learning and development. Learning is as much the acquisition of knowledge and development of skills, as it is the development of oneself in a broader community of practice, within which such knowledge and skills are valued and meaningful (Lave & Wenger, 1991; Rogoff, 2003; Vygotsky, 1978).

Recent national synthesis reports suggest that understanding science and engineering requires proficiency in multiple aspects of conceptual understanding, practices, and identification with a larger community (NRC, 2009; NRC, 2012). Effective science and engineering education cannot be purely a memorization of facts, nor can it be only the development of abstract skills. Becoming scientifically literate involves engaging in the practices of the scientific and engineering community. Two participation-oriented frameworks have emerged in the past few years to guide youth science education.

In 2009, the NRC published a synthesis report on informal science education, *Learning Science in Informal Environments*. The authors posited six strands of scientific practices that intertwined knowledge, skills, attitudes, and dispositions. Their assumption is that "effective science education reflects the ways in which scientists actually work" (NRC, 2009, p. 42). The report outlines six strands leading to effective informal science learning when opportunities are provided for a young person to (NRC, 2009, p. 4):

1. Experience excitement, interest, and motivation to learn about the natural world.
2. Generate, understand, remember, and use concepts, explanations, arguments, models, and facts.
3. Manipulate, test, explore, predict, question, observe, and make sense of the natural world.

4. Reflect on science as a way of knowing, on processes, concepts, and institutions of science.
5. Participate in scientific activities with others, using scientific language, and tools.
6. Think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science.

Another movement in science education is the establishment of new national standards for K-12 school-based science education. In the report *Framework for K-12 Science Education* the authors recognize scientific and engineering practices "shows that theory development, reasoning, and testing are components of a larger ensemble of activities..." (NRC, 2012, p. 43). Engaging in science and engineering practices can increase curiosity, interest, and improve motivation. The eight practices include:

1. Asking questions (science) and defining problems (engineering).
2. Developing and using models.
3. Planning and carrying out investigations.
4. Analyzing and interpreting data.
5. Using math and computers.
6. Constructing explanations (science) and designing solutions (engineering).
7. Engaging in argumentation.
8. Obtaining, evaluating and communicating information.

Rethinking 4-H SET Abilities

The latest 4-H efforts by Horton et al. (2007) recognize the need to intertwine content and abilities. Now 4-H science education programs need to embrace not only the intertwining of content and skills, but the role of participation in authentic communities of practice. Science and engineering are human enterprises. To be scientifically literate, youth need to jointly understand scientific and engineering concepts, be able to engage in scientific and engineering practices, and see themselves as consumers of and contributors to the scientific community. Intertwining science process skills, science content, and deepening participation in scientific communities may ultimately contribute to deeper levels of scientific literacy.

4-H programs offering science education, guided by the 4-H SET Checklist, should provide youth opportunities to participate in scientific and engineering practices—intertwining content, skills, and attitudes—and emphasize identity and attitude development. 4-H science education also needs to emphasize programming that is relevant to youths' lives and fosters learning, growth, and scienceinfused participation in family, community, and social settings. By recognizing and integrating emerging research into our work with program development, we ensure 4-H programs offer the best in high-quality informal science and engineering education.

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