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Scientific literacy: California 4-H defines it from citizens' perspective

by Martin H. Smith, Steven M. Worker, Andrea P. Ambrose *and* Lynn Schmitt-McQuitty

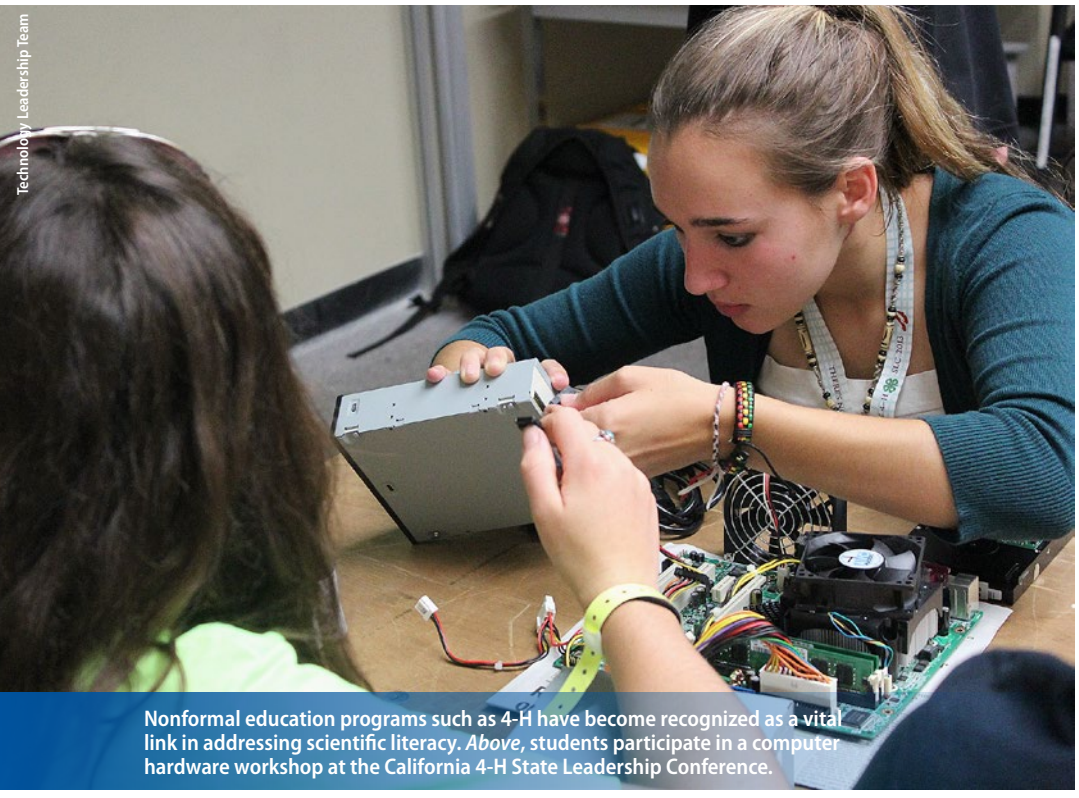
Scientific literacy is an important educational and societal goal. Measuring scientific literacy, however, has been problematic because there is no consensus regarding the meaning of scientific literacy. Most definitions focus on the content and processes of major science disciplines, ignoring social factors and citizens' needs. The authors developed a definition of scientific literacy for the California 4-H Program from the citizen's perspective, concentrating on real-world science-related situations. The definition includes four anchor points: science content; scientific reasoning skills; interest in and attitudes toward science; and contribution through applied participation. The definition provides the California 4-H Science, Engineering, and Technology Initiative with a framework for future science curriculum and program development and implementation, educator professional development, and evaluation.

It is widely agreed that scientific literacy is an important educational and societal goal (e.g., NAS 2007). Scientific literacy targets socially responsible and competent citizenry in that it enables individuals to participate in and contribute to a society that is shaped ever more by advances in science and technology (NAS 2007). However, scientific literacy is low among U.S. youth; poor achievement in science among K-12 students on large-scale assessments (e.g., NCES 2011) has raised national concerns (NAS 2007). Youth who lack foundational knowledge and skills in science will neither be able to pursue science careers nor participate fully in helping to address challenges such as climate change, future energy resources and consumer food choices (NAS 2007).

Addressing scientific literacy was identified as a Strategic Initiative of the 21st Century in the UC Agriculture and Natural Resources (UC ANR) Strategic Vision 2025 (Regents of UC 2009), a vision statement to help guide UC ANR research and extension programs through the early part of the 21st century. Advancing scientific literacy is described there as critical to "our collective future." Strategies outlined to help increase scientific literacy through UC ANR included the development, evaluation and extension of science education programs for youth that use effective pedagogy and increase civic engagement.

While there is agreement that advancing scientific literacy among K-12 youth is important, measuring it has been problematic since there is no consensus about the meaning or component parts of scientific literacy (DeBoer 2000; Roberts 2007). Although "a veritable deluge of definitions" (Roberts 2007, 729) have been developed, most have focused principally on the content and processes of major science disciplines while ignoring "the social aspects of science and the needs of citizenship" (Lang et al. 2006, 179). Furthermore, strategies used to assess scientific literacy have operated traditionally from a deficit-based viewpoint of what individuals should know about key science concepts considered to be important by scientists (Falk et al. 2007; Laugksch 2000).

Falk et al. (2007) postulate that science learning is contextualized; persons within a community have unique science knowledge bases due to the fact that each



Technology Leadership Team

Nonformal education programs such as 4-H have become recognized as a vital link in addressing scientific literacy. *Above*, students participate in a computer hardware workshop at the California 4-H State Leadership Conference.

Online: http://californiaagriculture.ucanr.edu/landingpage.cfm?article=ca.v069n02p92&fulltext=yes
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individual develops "an understanding of a specific area of science because of his or her unique, personal set of needs and desires to know about this area of science" (458). They argue further that an asset-based approach to assessing science understanding is more appropriate than a deficit-based strategy. In this scenario, measurements of scientific literacy focus on individuals' science understanding and abilities within relevant contexts (Falk et al. 2007). Referred to also as a sociological approach to assessing scientific literacy, this type of measurement involves small-scale contextualized studies rather than large-scale investigations that require representative samples from populations (Laugksch 2000).

Defining scientific literacy or describing its component parts is critical in order for the work of science program development to progress. The absence of a definition or agreed-upon understanding makes it challenging to develop and compare science programs, evaluate pedagogical strategies and perform outcome evaluations (Roberts 2007). However, because science learning is a function of context, attempting to reach consensus on a universal definition is imprudent (Roberts 2007). Therefore, any definition of scientific literacy "should be conceptualized broadly enough . . . to pursue the goals that are most suitable for [a given] situation" (DeBoer 2000, 582).

Learning environments

Science learning environments may be classified into three types: formal, nonformal and informal. Formal science education programs are classroom based, occurring in K-12 schools during school hours, with instruction facilitated by trained teachers (Carlson and Maxa 1997). Nonformal science education programs (e.g., 4-H, Girl Scouts, summer science camps) occur during out-of-school time and are normally led by adult staff or volunteer educators (Carlson and Maxa 1997; Walker and Dunham 2002). Informal science education programs (e.g., museums, zoos, technology centers and aquaria) occur outside of a school setting during out-of-school time and learning is typically self-directed (Carlson and Maxa 1997).

4-H science education

Nonformal education programs have become increasingly recognized as a vital link in addressing scientific literacy (Falk et al. 2007; National Research Council 2009). The 4-H Youth Development Program is a nonformal youth education program administered through the national Cooperative Extension system. Grounded in positive youth development practices that are focused on helping youth reach their fullest potential, 4-H offers curriculum projects and activities through county-based programs in all 50 states, the District of Columbia and internationally. With a diverse array of science-based curricula and resources ranging across multiple disciplines (UC ANR 2013), 4-H science programming is facilitated by staff and volunteers through hands-on experiential learning and inquiry strategies (Enfield et al. 2007).

In 2008, National 4-H strengthened its commitment to science education by introducing the 4-H Science Mission Mandate (4-H Science). This national effort provided strategic direction to improve science curricula and resources, professional development of staff and volunteers, partnerships with local, state and national organizations and agencies, fund development and evaluation. In response, the California 4-H Youth Development Program established its 4-H Science, Engineering and Technology (SET) Initiative (UC ANR 2008). The primary goals of the initiative are to improve youth scientific literacy through effective programming and advance the research base of nonformal youth science education (Worker and Smith 2014). During the 2013–2014 program year, 82,545 youth participated in SET projects in California (California State 4-H Office 2014).

4-H science programming is grounded in effective science pedagogy and positive youth development practices. Individuals develop an understanding of subject matter and advance their abilities through interactions with their environment that include youth-led investigations, active questioning, facilitated reflection

The Sacramento County 4-H Children, Youth and Families at Risk project focuses on science and technology literacy in its afterschool program.



Marianne Bird

and the application of knowledge and skills in ways that address real-world issues (Carver and Enfield 2006). Specific youth development practices are adapted from the National Research Council and Institute of Medicine (NRC/IOM) (2002), which include physical and psychological safety, supportive relationships, youth engagement, community involvement and opportunities for skill building. The targeted youth development outcomes are the six C's of positive youth development — caring, contribution, confidence, competence, character and connection (Lerner et al. 2010).

Citizens' perspective

Historically, as mentioned above, most definitions of scientific literacy have focused on generalized knowledge related to major science disciplines, principally content and processes germane to scientists as opposed to unique contexts or situations where science is of relevance to individual citizens (Roberts 2007). These "within science" definitions represent what Roberts (2007) referred to as a Vision I perspective of scientific literacy that is situated within the disciplines of science. In contrast, a Vision II perspective focuses on situations whereby scientific literacy is positioned from the viewpoint of the citizen and concentrates on science-related situations individuals may encounter in their lives (Roberts 2007). Although elements of both Vision I and Vision II are typically incorporated into definitions of scientific literacy in what Roberts (2007) refers to as "a kind of mating dance wherein they complement one another" (730), starting from a Vision II perspective is important when viewing science learning as a contextualized phenomenon.

A Vision II perspective is essential to define scientific literacy within the context of the California 4-H Youth Development Program. California 4-H educational programming is guided by environmental, social and economic issues (e.g., water conservation, quality and security; alternative energy; food safety and security) outlined in the UC ANR Strategic Vision 2025. A Vision II perspective allows the component parts that comprise scientific literacy to be specified broadly enough that they address these diverse societal issues yet also provide opportunities to develop 4-H science programming that is culturally relevant and specific to individual county-based 4-H programs.

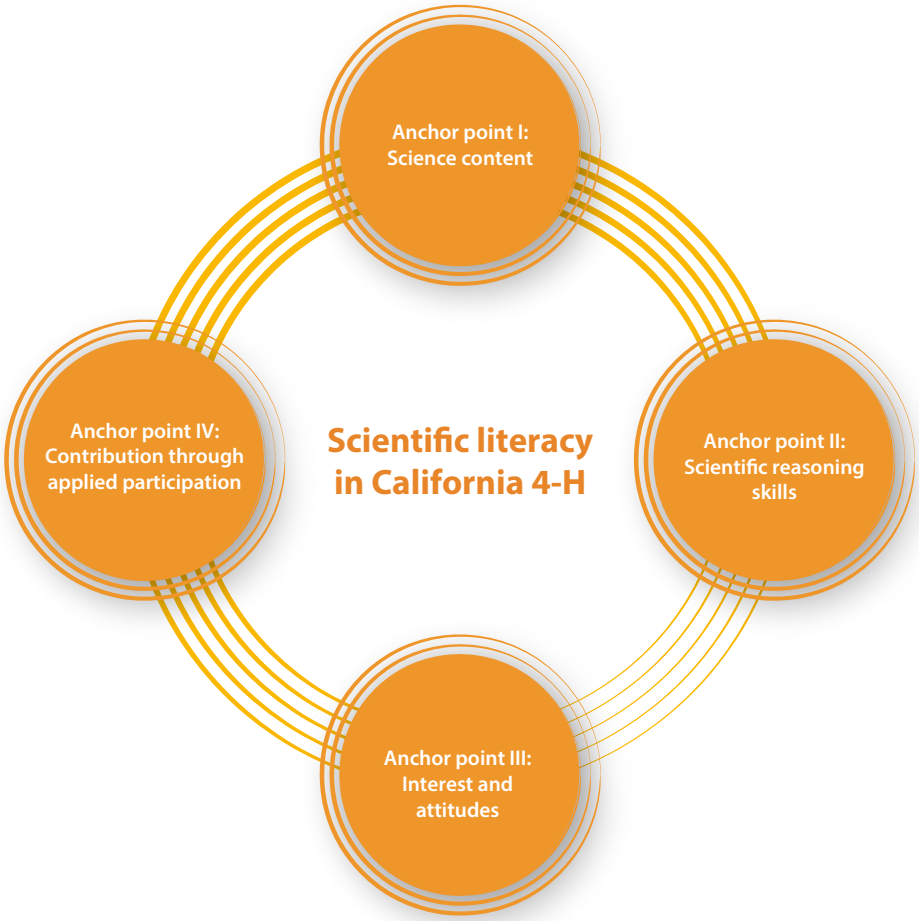


Fig. 1. Anchor points for youth scientific literacy in California 4-H.

Despite the importance of a Vision II perspective, however, elements of Vision I cannot be ignored. The issues facing California outlined in the UC ANR Strategic Vision 2025 require science- and research-based solutions. Thus, specific science content and practices (Vision I) remain critical to developing scientific literacy within California 4-H and must be incorporated effectively into science programming.

Anchor points

For the purpose of connecting a definition of scientific literacy within the context of California 4-H to previously published work, the authors completed a systematic, analytical literature review (Steward 2004). Specifically, the literature review synthesized key themes from relevant, peer-reviewed resources to help develop new ideas and understanding. Informed by this literature review, the authors identified four anchor points to define scientific literacy within the context of California 4-H: science content; scientific reasoning skills; interest and attitude; and contribution through applied participation (see fig. 1). These anchor points provide guideposts for curriculum and program development, teaching and evaluation, and are flexible enough for adaptation to local needs and situations.

Anchor point I: Science content. Content understanding is a key component of scientific literacy (Roberts 2007). However, rather than viewing scientific content as a generalized body of knowledge from the perspective of what scientists need to know (Vision I), the focus of this anchor point is on science-related content associated with issues relevant to citizens of California (Vision II) that were identified in collaboration with stakeholders from throughout the state (Regents of UC 2009). Specific examples include water resource management; sustainable food systems; sustainable natural ecosystems; food safety and security; management of endemic and invasive pests and diseases;

energy security and green technologies; and nutrition education and childhood obesity.

Anchor point II: Scientific reasoning skills. Scientific reasoning includes, generally, the cognitive skills needed to understand and evaluate scientific information (Giere et al. 2006). More specifically, it includes skills necessary to engage in the practices of science, such as asking questions, collecting data, analyzing and interpreting evidence, developing and using models, planning and carrying out investigations, making inferences and constructing explanations based on data, engaging in argumentation from evidence and communicating results (National Research Council 2012). Scientific reasoning skills are linked closely to the development of scientific knowledge. To make sense of scientific content, learners require reasoning skills so they can critique their knowledge claims and the claims of others (Ford 2008).

Anchor point III: Interest and attitudes. Enhancing interest in and attitudes toward science is essential to advancing scientific literacy among youth and the general population (National Research Council 2009). The authors included this as a third essential component for scientific literacy within the context of California 4-H, and it can be considered from both Vision I and Vision II perspectives: (1) education- and career-related choices are shaped by interest and attitudes (Else-Quest et al. 2013) and therefore can improve the likelihood that individuals will pursue careers in science (Vision I); and (2) interest and attitudes influence individuals' motivation, behavior and responses to science-related situations they encounter in their everyday lives (Bybee and McCrae 2011). Improved motivation can enhance willingness to engage in science-related issues as citizens in meaningful ways (Vision II) (Bybee and McCrae 2011). Furthermore, improving interest in and attitudes toward science is particularly relevant to women and ethnic minorities, groups that have more limited educational opportunities in science and are underrepresented in science-related careers (e.g., Else-Quest et al. 2013).

Anchor point IV: Contribution through applied participation. The authors identified the authentic application of knowledge and skills — application to real-world issues — as the fourth critical component for advancing scientific literacy within California 4-H. In order to enhance understanding and appreciation of context-specific science, Falk et al. (2007) advocate engaging the public in science by offering authentic, community-based opportunities related to the science they need or that interests them. The application of knowledge and skills in real-world contexts helps youth advance their critical thinking skills, gain a deeper understanding of science content (Jones 2012) and begin to identify with a larger scientific community (e.g., National Research Council 2009). Furthermore, community engagement in science promotes lifelong learning, allows for authentic participation at multiple levels (Lave and Wenger 1991), favors autonomous thinking and is a key element of experiential learning (Kolb 1984). In 4-H, community engagement is frequently carried out through service learning whereby youth apply knowledge and skills to address authentic community needs (e.g., Smith et al. 2010).

Advancing 4-H science

Emphasizing a "focus-on-situations approach" (Vision II) within the context of California 4-H provides opportunities for the systematic advancement of the 4-H SET Initiative using an asset-based approach to understanding science. This strategy emphasizes relevant science knowledge that individuals learn for different reasons, including interest, need and curiosity. The anchor points will be implemented by the California 4-H SET Initiative beginning in 2015. They will help California 4-H administrators, academic staff and program staff to: frame the development and adaptation of curriculum materials; shape the content and design of professional development for 4-H staff and volunteers; and use consistent outcome goals for program evaluation.

Curriculum development and adaptation. Deng (2011) describes three levels of discourse regarding curriculum development: institutional, "that which is valued and sought after by members of a society" (46); programmatic, which refers to the translation of institutional goals into curriculum documents and materials; and classroom, that, when viewed broadly, refers to the implementation of curriculum activities by educators with their target audiences. By defining scientific literacy using a Vision II perspective, the institutional and programmatic levels of discourse concerning curriculum development in California 4-H will be driven by issues and situations important to citizens of California outlined in the UC ANR Strategic Vision 2025. Furthermore, all curriculum materials, regardless of science content area, will attend to anchor points II (scientific reasoning skills), III (interest and attitudes) and IV (contribution through applied participation). The classroom level of discourse — curriculum implementation — will be determined by the needs and interests of youth in individual county-based 4-H programs. This will allow each county-based program to work collaboratively with internal and external stakeholders and focus on specific issues within their county or region.

Professional development. The knowledge and skills of science educators have a demonstrated positive effect on learner outcomes; therefore, professional development to build educators' capacity is



Enhancing interest in science is essential to advancing scientific literacy among youth. *Right*, San Mateo County 4-H members feeding goats.



Steven Worker

Applying knowledge to real-world issues is a critical component of scientific literacy. *Above*, planting the millionth tree in the 4-H Million Trees Project, which was created by a 4-H member to reduce atmospheric carbon dioxide.

an essential investment to advance science learning (Stiles and Mundry 2002). In California 4-H, effective professional development is needed to build the capacity of staff and volunteers to understand the 4-H SET Initiative and implement effective nonformal science programming (Schmitt-McQuitty et al. 2014; Smith and Schmitt-McQuitty 2013).

Utilizing a Vision II approach to defining scientific literacy will help in designing professional development opportunities for 4-H staff and volunteers that incorporate specific features considered critical to advancing the knowledge and skills of science educators: emphasis on subject matter knowledge (e.g., Penuel et al. 2007); and linking professional development to broader organizational goals (e.g., Loucks-Horsley et al. 2003). For 4-H, the subject matter and organizational priorities will be the science-related issues of importance to California citizens.

Evaluation. The evaluation of nonformal science learning involves members of the target audience demonstrating "how they understand science concepts and make connections between concepts and skills and their lived experiences" (Cox-Petersen and Olson 2002, 105), their attitudes towards science (Osborne et al. 2003) and interest in science learning activities (Krishnamurthi et al. 2013). When viewing evaluation in this manner, the four anchor points provide a framework for consistent, measurable learning goals that can be used for formative (program and activity improvement) and summative (outcome) evaluation of California 4-H SET programming. Formative assessment using the four anchor points will be used to provide data-driven improvements with respect to the development and adaptation of curriculum materials, state and county-based science programming, and educator professional development. Summative evaluation will target the four anchor points through the use of appropriate evaluation methods. Specifically, the assessment of content understanding (anchor point I) and contributions made by learners through applied participation (anchor point IV) will be designed around the specific environmental, social and economic issues outlined in the UC ANR Strategic Vision 2025 that are being addressed through 4-H SET programs. Scientific reasoning skills (anchor point II) and interest and attitudes (anchor point III) will be measured in all content areas and will provide the opportunity for comparisons across 4-H SET programs.

Benefits to California. Most aspects of 21st century life are impacted by science. Associated political and economic challenges are complex and related decisions require sound choices made by a scientifically literate populace (NAS 2007; Regents of UC 2009). From this perspective, scientific literacy can be viewed as an essential form of human capital, one that is critical to developing an informed and economically competitive societal infrastructure with a productive and efficient workforce (McEneaney 2003). Accordingly, increasing scientific literacy can help advance economic prosperity, enhance environmental sustainability, develop energy technologies and improve human health (NAS 2007; Regents of UC 2009).

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When viewing scientific literacy from the perspective of societal infrastructure, it is important to acknowledge the intersection between science and society and the changing relationship between science and the public. By emphasizing a focus-on-situations approach to scientific literacy (Vision II) (Roberts 2007), the intersection between science and society involves citizens in framing and resolving scientific issues as opposed to the previous social contract science had with society that was based on a degree of separation between scientists and the public (Gibbons 1999). Gallopín et al. (2001) and Gibbons (1999) discuss the importance of developing a new contract between science and society, one where science has a more pragmatic aim that involves the public in identifying and addressing relevant issues, works within real-world contexts and produces new knowledge, products and processes that address specific societal needs.

Improving youth scientific literacy through a Vision II approach can help strengthen California's economy by building the capacity of the future workforce and advancing a new social contract between science and society. By focusing on science-related situations youth may encounter in their daily lives, educators can help advance their scientific literacy in a manner that enables them to address relevant issues related to agriculture, the environment and human resources outlined in the UC ANR Strategic Vision 2025. According to Feinstein (2011), this is the fundamental usefulness of scientific literacy: Helping individuals address "meaningful problems in their lives, directly affect their material and social circumstances, shape their behavior and inform their most significant practical and political decisions" (169).

Beyond California 4-H. The definition of scientific literacy using four anchor points developed for the California 4-H Youth Development Program is adaptable for use by other state 4-H programs. Since the National 4-H Youth Development Program includes, by its nature, 50 context-specific state programs, each addressing particular needs relative to the youth populations they serve, the focus-on-situations approach (Roberts 2007)

used for California 4-H could be modified and positioned around issues relevant to circumstances in each state.

Specifically, anchor points I (science content) and IV (contribution through applied participation) provide for adaptability within different contexts. Individual state 4-H programs could identify relevant content and associated service learning projects that provide youth opportunities for applied participation. For example, science-related issues around marine ecology could be a subject matter and service learning focus for 4-H programs in some coastal states, whereas sustainable agriculture might be a concern germane to citizens in crop-producing states in other parts of the country. In comparison, anchor points II (scientific reasoning skills) and III (interest and attitudes) are broad constructs that could remain consistent across diverse subject matter areas within different contexts.

Implications for 4-H science

The four anchor points identified as the component parts to scientific literacy will provide California 4-H with a consistent framework for science curriculum and program development and implementation; educator professional development; and evaluation. More specifically, this focus-on-situations perspective (Roberts 2007) will center science education programming on science-related issues to California as defined by the UC ANR Strategic Vision 2025 and measurements of scientific literacy will utilize an asset-based approach grounded in individuals' understanding and abilities within areas of science germane to their needs and interests. Additionally, further work will focus on the extent to which the four anchor points support the evaluation of scientific literacy. Lastly, the definition of scientific literacy developed for the California 4-H Youth Development Program is broad enough that it can be adapted for use in other contexts. CA

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References

Bybee R, McCrae B. 2011. Scientific literacy and student attitudes: Perspectives from PISA 2006 science. Int J Sci Educ 33(1):7–26.

California State 4-H Office. 2014. California 4-H Enrollment Report 2014. UC ANR.

Carlson S, Maxa S. 1997. Science Guidelines for Nonformal Education. Washington, DC: USDA, Cooperative Extension Service, Children, Youth, and Family Network.

Carver RL, Enfield RP. 2006. John Dewey's philosophy of education is alive and well. Educ Culture 22(1):55–67. http://docs.lib.purdue.edu/eandc/vol22/iss1/art6.

Cox-Petersen AM, Olson JK. 2002. Assessing student learning. In Bybee RW (ed.). *Learning Science and the Science of Learning*. Arlington, VA: NSTA Press.

DeBoer G. 2000. Scientific literacy: Another look at its historical and contemporary meanings and its relationship to science education reform. J Res Sci Teach 37(6):582–601.

Deng Z. 2011. Scientific literacy: Content and curriculum making. In: Linder C, Ostman L, Roberts D, et al. (eds.). *Exploring the Landscape of Scientific Literacy*. New York: Routledge. p 45–56.

Else-Quest NM, Mineo CC, Higgins AH. 2013. Math and science attitudes and achievement at the intersection of gender and ethnicity. Psychol Women Quart 37(3):293–309.

Enfield RP, Schmitt-McQuitty L, Smith MH. 2007. The development and evaluation of experiential learning workshops for 4-H volunteers. J Extension (on-line) 45(1). Article 1FEA2. www.joe.org/joe/2007february/a2.php.

Falk JH, Storksdieck M, Dierking LD. 2007. Investigating public science interest and understanding: Evidence for the importance of free-choice learning. Public Underst Sci 16:455–69.

Feinstein N. 2011. Salvaging science literacy. Sci Educ 95(1):168–85.

Ford M. 2008. Disciplinary authority and accountability in scientific practice and learning. Sci Educ 92:404–23.

Gallopín GC, Funtowicz S, O'Connor M, et al. 2001. Science for the twenty-first century: From social contract to the scientific core. Int Soc Sci J 47(168):219–29.

Gibbons M. 1999. Science's new social contract with society. Nature 402 (6761 Suppl):C81–4.

Giere RN, Bickle J, Mauldin RF. 2006. *Understanding Scientific Reasoning*. Belmond, CA: Thomson/Wadsworth.

Jones RA. 2012. What were they thinking? Instructional strategies that encourage critical thinking. Sci Teacher 79(3):66–70.

Kolb DA. 1984. *Experiential Learning: Experience as the Source of Learning and Development*. Upper Saddle River, NJ: Prentice Hall.

Krishnamurthi A, Bevan B, Rinehart J, et al. 2013. What afterschool STEM does best. Afterschool Matters 18:42–9.

Lang M, Drake S, Olson J. 2006. Discourse and the new didactics of scientific literacy. J Curriculum Stud 38(2):177–88.

Laugksch RC. 2000. Scientific literacy: A conceptual overview. Sci Educ 84(1):71–94.

Lave J, Wenger E. 1991. *Situated Learning: Legitimate Peripheral Participation*. Cambridge University Press.

Lerner RM, von Eye A, Lerner JV, et al. 2010. Special issue introduction. The meaning and measurement of thriving: A view of the issues. J Youth Adolescence 39(7):707–19.

Loucks-Horsley S, Love N, Stiles K, et al. 2003. *Designing Professional Development for Teachers of Science and Mathematics* (2nd ed.). Thousand Oaks, CA: Corwin Press.

McEneaney EH. 2003. The worldwide cachet of scientific literacy. Comp Educ Rev 47(2):217–37.

[NAS] National Academy of Sciences. 2007. *Rising above the gathering storm: Energizing and employing America for a brighter economic future*. Washington, DC: National Academies Press.

National Research Council. 2009. *Learning Science in Informal Environments: People, Places, and Pursuits*. Washington, DC: National Academies Press.

National Research Council. 2012. *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, DC: National Academies Press.

[NCES] National Center for Education Statistics. 2011. The Nation's Report Card: Science 2009. NCES 2011-451. Institute of Education Sciences, US Department of Education, Washington, DC. http://nces.ed.gov/nationsreportcard/pdf/main2009/2011451.pdf.

[NRC/IOM] National Research Council and Institute of Medicine. 2002. *Community Programs to Promote Youth Development*. Washington, DC: National Academies Press.

Osborne J, Simon S, Collins S. 2003. Attitudes towards science: A review of the literature and its implications. Int J Sci Educ 25(9):1049–79.

Penuel W, Fishman B, Yamaguchi R, Gallagher L. 2007. What makes professional development effective? Strategies that foster curriculum implementation. Am Educ Res J 44(4):921–58.

Regents of UC. 2009. UC Division of Agriculture and Natural Resources Strategic Vision 2025. Oakland, CA. http://ucanr.org/files/906.pdf.

Roberts DA. 2007. Scientific literacy/Science literacy. In: Abell SK, Lederman NG (eds.). *Handbook of Research on Science Education*. p 729–80. Mahway, NJ: Lawrence Erlbaum.

Schmitt-McQuitty L, Carlos RM, Smith MH. 2014. Learnings and Recommendations to Advance 4-H Science Readiness. J Extension 52(4):1FEA2. www.joe.org/joe/2014august/a1.php

Smith MH, Worker SM, Kelly M et al. 2010. *There's No New Water!* Chevy Chase, MD: National 4-H Council.

Smith MH, Schmitt-McQuitty L. 2013. More effective professional development can help 4-H volunteers address need for youth scientific literacy. Calif Agr 67(1):54–61.

Steward B. 2004. Writing a literature review. Brit J Occupational Therapy 67(11):495–500.

Stiles KE, Mundry S. 2002. Professional development and how teachers learn: Developing expert science teachers. In: Bybee RW (ed.). *Learning Science and the Science of Learning*. Arlington, VA: Natinal Science Teachers Association Press. p 137–51.

[UC ANR] UC Agriculture and Natural Resources. 2008. 4-H Launches SET. ANR Report 22(3):3. http://ucanr.org/sites/anrstaff/anrreport/archive/reportarchive/report08/rptpdf08/september-2008.pdf.

[UC ANR] UC Agriculture and Natural Resources. 2013. Project Areas. 4-H Youth Development Program, UC Davis. http://4h.ucanr.edu/Projects/.

Walker J, Dunham T. 2002. Understanding Youth Development Work. University of Minnesota Extension Service, College of Education, Center for 4-H Youth Development, Minneapolis, MN.

Worker SM, Smith MH. Fall 2014. Curriculum and professional development for OST science education: Lessons learned from California 4-H. Afterschool Matters 21–7. www.niost.org/Table/Afterschool-Matters/Afterschool-Matters-Fall-2014/.